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35 REVOLUTIONARY INNOVATORS

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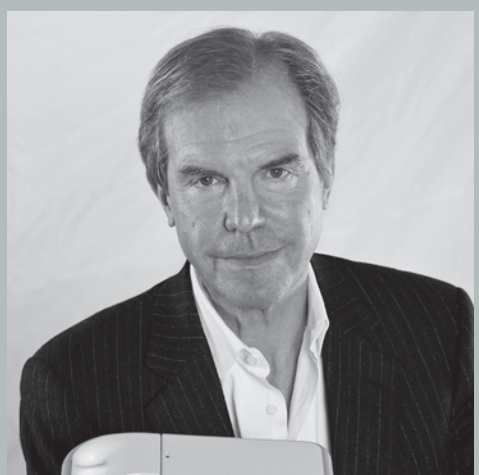

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One Laptop Per Child

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- **Rodney Brooks**, founder of Rethink Robotics, on retooling manufacturing with a new generation of industrial robots
- **Charles Dages**, executive vice president for emerging technology at Warner Brothers, on surprising ways that technology is enabling a more engaging entertainment experience
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technology review

Ren Ng
ENTREPRENEUR OF THE YEAR
p. 26

Photograph by Timothy Archibald

25

35 INNOVATORS UNDER 35

Our latest group of 35 young innovators features people whose contributions in energy, medicine, computing, and materials will influence the direction of human affairs.

By THE EDITORS

COVER ILLUSTRATION BY HARRY CAMPBELL

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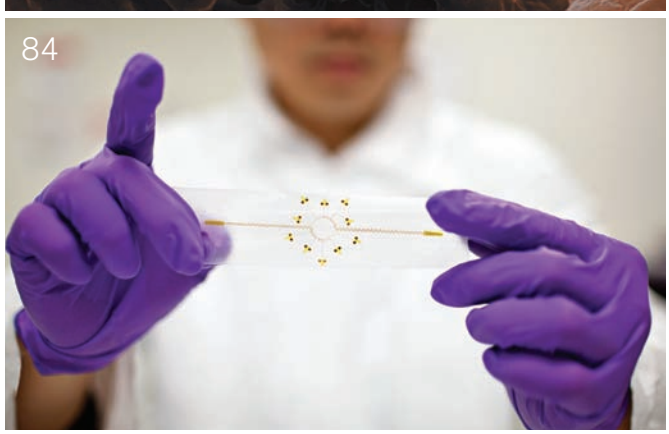

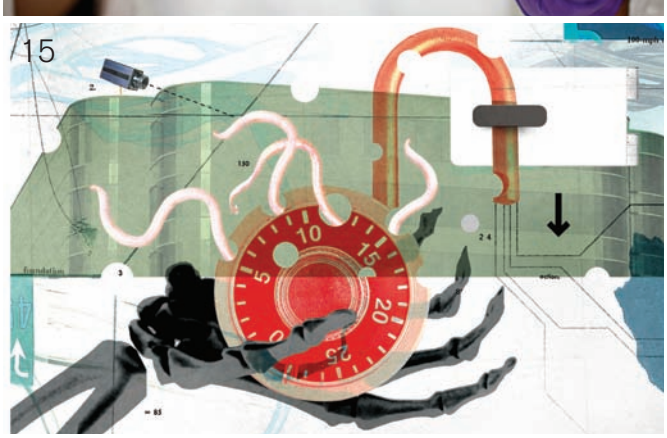

WHY TODAY'S SMARTEST SYSTEMS

The good news is IT solutions are now more sophisticated. The bad news is they're also more complicated. And all this complexity is taking its toll.

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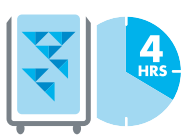

IBM PureSystems can be up and running in under four hours.[2]

What goes into a PureSystem?

- *Built-in expertise*
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with clients and partners, has been turned into a pattern of expertise. An IBM PureSystem can follow this pattern to automatically set up a database infrastructure in minutes. The system then monitors how the database is being used, tuning it as conditions change.

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IBM PureSystems have been able to achieve up to twice the business application performance and up to twice the application density as conventional approaches.[3]

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HAVE BUILT-IN EXPERTISE.

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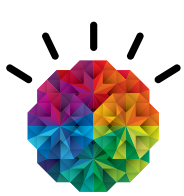

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Unlike today's "converged" IT solutions, IBM PureSystems are more than just prepackaged bundles of hardware and software; these systems are integrated by design, using built-in expertise to balance and coordinate IT resources to create a radically simplified experience for the end user.

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1. Based on a 2011 commissioned study conducted by Forrester Consulting on behalf of IBM. 2. Based upon testing of the IBM PureApplication System W1500-96 with time measured from powering on the system to when it is ready to support application deployments and based upon testing of the IBM PureFlex System Express & Standard models containing one chassis and one compute node with the time measured from powering on the system to when it is ready to support a virtual image deployment. 3. Up to 2X application density based upon simulations of virtualized applications on an IBM Flex System x240 Compute Node as compared to a previous generation IBM system. The IBM Flex System x240 Compute Node is available in IBM PureFlex System and IBM PureApplication System. Up to 2X performance of business applications based upon testing of IBM Storwize v7000 "Easy Tier" on previous generation IBM system. IBM Storwize v7000 is included in IBM PureFlex System and IBM PureApplication System. IBM, the IBM logo, ibm.com, PureSystems, Smarter Planet and the planet icon are trademarks of International Business Machines Corp, registered in many jurisdictions worldwide. A current list of IBM trademarks is available on the Web at www.ibm.com/legal/copytrade.shtml.

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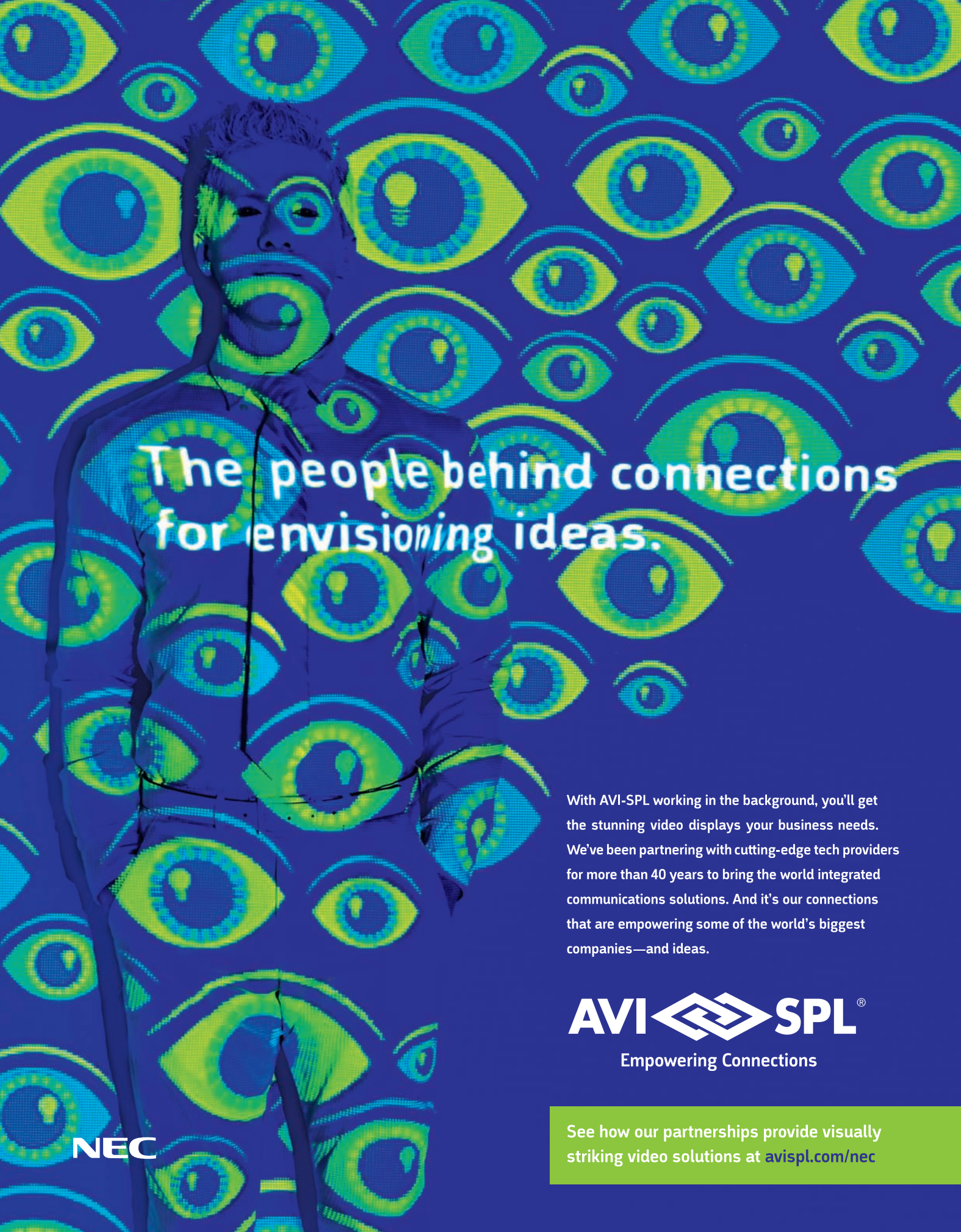

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"What Facebook Knows," July/August 2012

"There can be no concern for privacy when you *voluntarily* give up your personal information."

Peter Glassman, Schaumburg, Illinois

FACE FACTS Michael Wolff's takedown of Facebook's advertising strategy ("The Facebook Fallacy") wasn't the only piece from our July/August issue to draw hundreds of letters and comments—but it was the one with the most passionate objections. "Wow, what an incredibly ignorant understatement of Facebook's raw power in numbers," wrote **Fremitus** in an online comment. "To actually think that they will just use 10-year-old concepts (pop-ups and banners) as their big idea is ludicrous. The biggest reason to go public is to have cash on hand, and for what? For buying smaller companies that are doing innovative things. That's the big idea, someone else's. Just like Google and everyone else."

July/August 2012

AnsonA4 wrote in to thank Wolff for the article and claimed, "It made me think deeply about the situation. In the end, however, I think you are absolutely wrong about the demise of Facebook. Right now the majority of Facebook's revenues come from display advertisements, yes, but that will change in the future. They will start selling products similar to Amazon—you will be able to buy movies and music, and advertising will become much more rich. You're almost completely ignoring the power and value of the information that Facebook already has and is gaining every day. There really is no clear way of stopping Facebook at this point—the information they have is too valuable and marketable."

Our related cover story on Facebook's use of our personal data, "What Facebook Knows," by senior IT editor Tom Simonite, inspired **Peter Glassman** of Schaumburg, Illinois, to wonder if we have any right to demand our privacy with regard to Facebook in the first place. "There can be no concern for privacy when you *voluntarily* give up your personal information. And for what? It's not like giving your personal info to a bank and they give you a credit card in return. What does Facebook give you? More advertising."

CHEAPLY GREEN In "The Great German Energy Experiment," our chief correspondent, David Talbot, investigated Germany's ambitious plans to slash its greenhouse-gas output. One online commenter, **Elidyl**, took a look at the cost of those plans and found them downright cheap. "Talbot writes: 'Various economic think tanks predict that the country will spend somewhere between $125 billion and $250 billion on infrastructure expansion and subsidies in the next eight years.' Another way to look at it: initial projections

JOIN THE DISCUSSION, OR CONTACT US

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for the costs of Fukushima are running around $81 billion for three power plants in meltdown. Alternatively, the Iraq War ran into the range of $300 million a day. The Germans have the strongest economy in Europe. It looks very good to me."

HOW'S THE VIEW IN THERE? In "You Will Want Google Goggles," Farhad Manjoo suggested that we'll quickly get over the dork factor and instead focus on the utility of Google's upcoming augmented-reality glasses. **Windchaser** thought that sounded just about right: "It was only a year or two ago that I first saw a 'link to Facebook' button at the bottom of a news article, and it seemed like such a natural addition to Facebook's abilities. Now I notice the lack of such a button. We're social creatures. I think the Google Goggles will just keep taking this further."

REGRETS, WE'VE HAD A FEW Another ferocious online debate erupted around editor in chief and publisher Jason Pontin's review "Why Publishers Don't Like Apps," which discussed *Technology Review*'s unsatisfying experience developing an iPad app with a replica of the magazine. Although some readers praised Pontin for his honesty, others felt he'd bailed out on the project too quickly. "It is sad to read an article so full of disappointment and frustration," wrote **RJH**. "Although it feels like the iPad has been around for a long time, it has been only two years since we've had it in our hands. This is an early market. Don't blame it on apps. The format doesn't matter—it's your content that attracts readers and advertisers."

Other readers felt Pontin nailed it: "I kind of suspect that the majority of people who are most offended by Mr. Pontin's reasoning have an economic stake in app development," wrote **Josefski**. "Most people's criticism boils down to: 'You should have tried this proprietary solution instead of the other proprietary solution' or 'You should have hired better developers.' Neither of which addresses the core issue, which is that publishers are content providers, not software companies. That is why markup languages were created—so publishers don't have to waste their time with code." tr

ENERGY

Engine Reinvention

Novel engine designs could help meet our growing demand for energy, says Shannon Miller.

Today, the U.S. electrical grid delivers power from fossil-based fuels to the end user with an average efficiency of just 33 percent. We need to improve that not just for the sake of the environment but to find the additional 214 gigawatts of electrical generation capacity that the Edison Foundation says we'll need by 2030.

Most of today's innovation for higher-efficiency power systems focuses on new technologies such as solar, wind, and fuel cells. Work in areas such as improving the reaction rates at fuel-cell cathodes and lowering manufacturing costs for solar cells has advanced those technologies significantly, but they still need a lot of work to become cost-effective. In the meantime, the bulk of our power generation comes from more established technologies such as conventional reciprocating engines and turbines. Gas and steam turbines, such as those in power plants, typically operate at power scales greater than 10 megawatts, while generators with reciprocating engines similar to those in cars usually operate at lower power. Improving conventional reciprocating engines could combine their existing benefits such as high reliability and low cost with significantly higher efficiencies and lower emissions.

One way to improve the efficiency of conventional engines is to modify existing designs. For instance, new technology for the piston rings that seal in high-pressure gases could lower frictional losses as the pistons move inside the engine cylinder; adjustments to valve timing could reduce the energy that escapes with an engine's exhaust. However, engine designs are already approaching the theoretical limits of their current architectures. Calculations tell us that a naturally aspirated conventional reciprocating engine can have a maximum efficiency near 45 percent, and such engines achieve near 35 percent in practice. Reaching efficiencies of 50 percent or greater in practice requires completely new engine architectures with theoretical efficiencies greater than 60 percent.

That's an approach we are taking, by starting with the fundamental thermodynamics at work in an engine. Models suggest areas that we can optimize to reduce energy losses, and that can point to new architectures. Engines that operate at higher compression ratios, for instance, reduce both combustion losses and the energy lost in exhaust. The resulting engines will be different from those we use today and will require significant development, but progress should be faster than it will be for less established new energy technologies. tr

Shannon Miller (profiled on p. 41) is a cofounder and the CEO of EtaGen, a startup working on high-efficiency engine designs for power generation.

COMPUTING

Incubating Programmers

Gadgets aren't made hackable enough to encourage young people to become innovators in computing, says Eben Upton.

Today's kids are proficient computer users but usually know little about what's happening under the hood. The Raspberry Pi, a $25 computer the size of a credit card, is my attempt to fix this problem—and to create a new generation of engineers.

I bought my first computer in 1989 at the age of 11. It was a BBC Micro "Model B" with 32 kilobytes of RAM and a two-megahertz 6502 processor, and I bought it with games and schoolwork in mind. But in common with many in my generation, I found myself using it to write simple programs and got my first experience of engineering. When I arrived at the University of Cambridge to study computer science in 1996, I found myself surrounded by people who had been exposed to the same sort of computing environment.

The situation had changed beyond recognition by the time I joined the university teaching staff in 2004 and began interviewing prospective students for that same computer science course. Applicant numbers had halved, and HTML had replaced

VIVIENNE FLESHER

assembly language in the typical skill set. A major culprit in that decline was the replacement of eight-bit microcomputers in the home by game consoles and PCs. Game consoles are designed to be nonprogrammable, and modern PCs, with their graphical interfaces and polished programs, strongly discourage programming. A person must now go out of his or her way to get a taste of programming, though it used to be the default thanks to computers that booted to a simple command prompt.

In 2006, along with some colleagues, I began to contemplate trying to fill this now-empty niche with a programmable machine for children. After six years of development, the Raspberry Pi was the result. It's a Linux PC that a child can plug into an old television and use to get the same sort of experience I had with my BBC Micro in 1989. Our machine is capable of sophisticated graphics that engage children accustomed to modern computer games. It also comes packed with development tools suitable for students from kindergarten to college. I hope it will lead many more children to learn programming and, eventually, increase the number of applicants to courses in computer science and electrical engineering.

People often ask me why teaching children to program matters, since they seem so extraordinarily competent at using tablets, phones, and PCs. My answer is that society is in desperate need of a new generation of engineers, not just to design the next shiny computing gadget but to tackle the wider challenges that we face over the coming century.

Alongside this, engineering and programming can be enormously rewarding both intellectually and financially. Who wouldn't want to equip their children for a life of playing with toys and getting paid for it? tr

Eben Upton (profiled on p. 42) is the founder of the Raspberry Pi Foundation, which aims to stimulate teaching of basic computer science.

MEDICINE

Personal Defenses

Cataloguing the uniqueness of an individual immune system offers a new understanding of disease, says Christina Fan.

Our immune system defends us from attack by foreign agents such as viruses and bacteria, in most cases without our even knowing. Much of the work is done by the B and T cells, known as lymphocytes. They produce proteins that recognize antigens and trigger the appropriate immune responses to remove the invaders.

To combat a wide variety of pathogens, an individual's defensive proteins, known as immunoglobulins and T-cell receptors, have to be extremely diverse in their molecular structure. It is estimated that a healthy individual carries 10 million different versions of these proteins. As the Nobel Prize–winning scientist Susumu Tonegawa explained in 1976, this diversity is the result of special genetic recombination and mutation at work in lymphocytes when they divide. The variety of defensive proteins an individual harbors at one time is known collectively as the immune repertoire.

A person's immune repertoire is dynamic, changing continuously under the influence of genetic background, age, vaccinations, environmental exposure, and diseases such as immune disorders. One reason some elderly people are more susceptible to infections is that the diversity of their repertoire declines.

Immunologists have long wanted a way to document the diversity of a person's immune repertoire. Only today is this becoming possible. Directly identifying the immune proteins in all their variety proved too challenging, but the discovery of the genetic machinery that creates those proteins suggested that sequencing the genes would be an easier alternative. In the last five years, advances in massively parallel sequencing technologies have made that feasible. Scientists can now affordably and quickly examine the genes from millions of lymphocytes taken from a single individual to understand the range of different proteins these can produce, obtaining a broad statistical catalogue of the subject's immune repertoire and its diversity.

High-throughput sequencing of a person's immune repertoire has many potential applications in medicine. The first clinical tests based on it have recently become available as a way to monitor lymphoma and leukemia patients for relapse. As scientists begin to study the repertoires of many different individuals over time, they may discover novel markers that could be used to assess the efficacy of vaccinations, the progress of autoimmune disorders, and the response of cancers to immunotherapy. The immune repertoire may also become an important part of the coming age of personalized medicine, since evidence suggests that autism, chronic fatigue syndrome, and other poorly understood conditions may be related to immune-system dysfunction. In the far future, knowledge about the immune repertoire could even inform genetic engineering to give a person super-immunity or to reverse immune disorders. tr

Christina Fan (profiled on p. 47) is a research scientist with ImmuMetrix, a company working on techniques for immune-repertoire sequencing.

35 Innovators Under the Age of 35

How the year's most promising technologists are chosen, and why we insist on their youth

Since 1999, *Technology Review* has selected 35 exceptionally talented young innovators whose work we, their peers, and a distinguished panel of judges have agreed has the greatest potential to transform the world.

The list has become an important recognition among technologists at startups, in industry, and in the academy, and we take seriously the responsibility of choosing the winners. We seek nominations more than six months before we publish the final list. Candidates are nominated through a form on TechnologyReview.com or by an editor. The nominees are screened for easy rejections, and we collect curricula vitae, personal statements, and at least three reference letters for those we like. A panel of judges—experts in different fields, who may be past winners themselves—assess the candidates. The editors consider a final list of dozens of names, scrutinizing the judges' comments and seeking a mixture of individuals that represents current trends in technology and the diversity of innovation around the globe. The list is whittled down until 35 remain.

Over the years, we've had some success in choosing women and men whose innovations and companies have been profoundly influential on the direction of human affairs. Previous winners include Larry Page and Sergey Brin, the cofounders of Google; Mark Zuckerberg, the cofounder of Facebook; Jonathan Ive, the chief designer of Apple; Helen Greiner, the cofounder of iRobot; Max Levchin, the cofounder of PayPal and founder of Slide; David Karp, the creator of Tumblr; and MIT neuroscientist Ed Boyden, one of the inventors of the emerging field of optogenetics, which makes it possible to control thought and memory. Even our least famous winners have gone on to distinguished careers. We're proud of our selections and the variety of achievements they celebrate.

But by far the most common question I hear about the young innovators is: why do you restrict nominees to technologists under the age of 35? What's with the youth chauvinism? Don't you think people 35 or older have the capacity to be truly innovative?

Of course I do. (If nothing else, I must if I am to come to work in the mornings: I turned 45 in May.) The history of technology is replete with examples of world-historical innovations by people in middle, late-middle, or even old age. Of Thomas Edison's 1,093 U.S. patents, only about 300 were filed before he was 35 years old. Steve Jobs was 52 in 2007, when he first unveiled the iPhone.

The reasoning behind the age qualification is mainly journalistic. Our list of innovators is not primarily a list of the most innovative people in the world, because such a list would inevitably be composed of men and women well known to our audience. It is a list of young people, because we hope to introduce you to personalities of whom you've never heard and eventually claim credit for our prescience. In short, a list of young innovators is just more interesting.

I won't tire you by listing some of 2012's young innovators. Read the list yourself, beginning on page 25, and write to me and tell me what you think at jason.pontin@technologyreview.com.

MARK OSTOW

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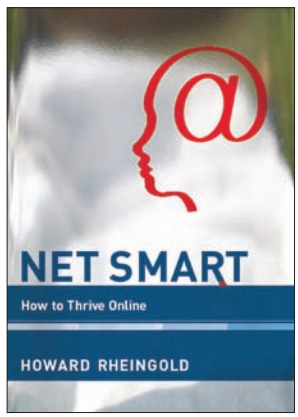

NET SMART

How to Thrive Online

Howard Rheingold

"The social media landscape changes quicker than you can say 'future shock.' As soon as you think you've mastered one network, another pops up, demanding its share of time and attention… *Net Smart* is a lifeboat for people who want to participate in new technologies without drowning in the flood."

— Daniel H. Pink, author of *Drive* and *A Whole New Mind*

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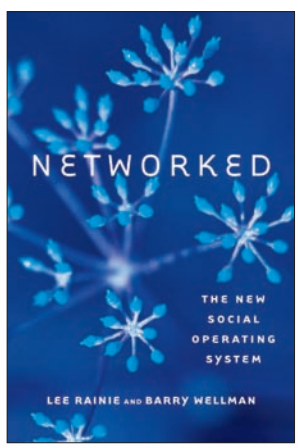

NETWORKED

The New Social Operating System

Lee Rainie and Barry Wellman

"Lee Rainie and Barry Wellman have woven three enormous changes in the ways we connect—the spread of the internet, mobile tools, and social media—into a single clarifying story of our present and future life in the 21st century."

— Clay Shirky, author of *Cognitive Surplus* and *Here Comes Everybody*

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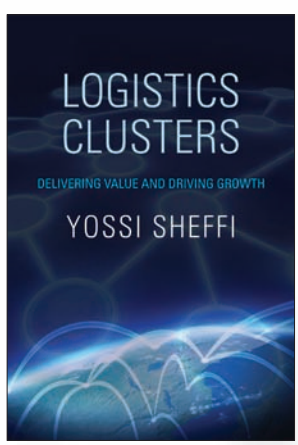

LOGISTICS CLUSTERS

Delivering Value and Driving Growth

Yossi Sheffi

"This book provides valuable insights for business leaders who are building their global and Asian supply chains. Based on solid research and practical examples, Dr. Sheffi offers a perceptive understanding of the roles governments, businesses and academia can play to create an enabling environment for logistics clusters to thrive."

— Leo Yip, Chairman, Singapore Economic Development Board

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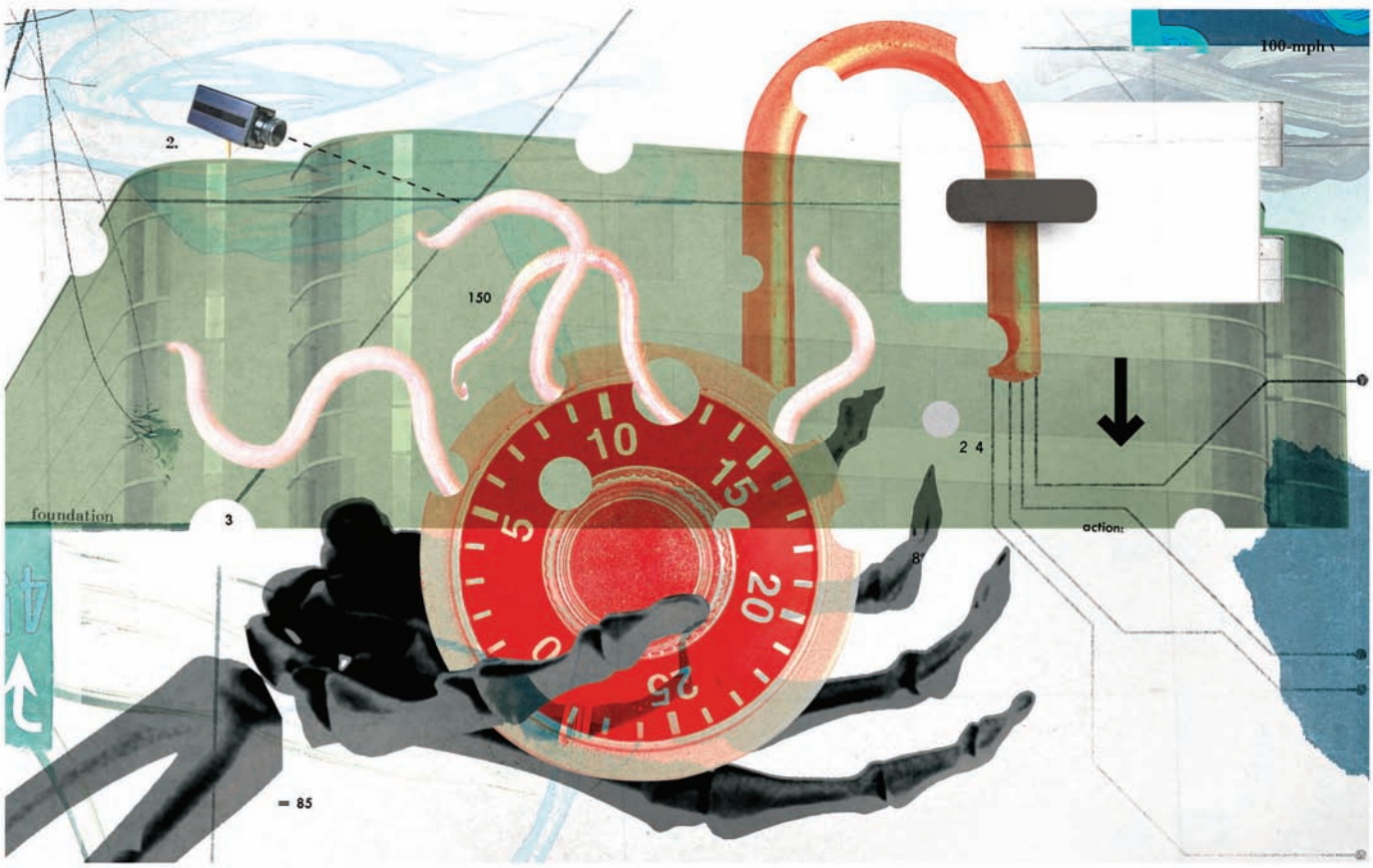

STUART BRADFORD

COMPUTING

The Antivirus Era Is Over

Conventional security software is powerless against today's sophisticated attacks. But alternative approaches are just getting started.

This summer, computer security labs in Iran, Russia, and Hungary announced the discovery of Flame, which Hungary's CrySyS Lab called "the most complex malware ever found."

For at least two years, Flame had been copying documents, taking screenshots, and recording audio, keystrokes, and Skype calls from infected computers. It relayed this stolen information to servers operated by its creators. And in all that time, no security software raised the alarm.

The discovery of Flame is just the latest in a series of incidents suggesting that conventional antivirus software is an outmoded way of protecting computers against malware. "Flame was a failure for the antivirus industry," wrote Mikko Hypponen, the founder of the antivirus firm F-Secure. "We really should have been able to do better. But we didn't. We were out of our league, in our own game."

Computer security programs for businesses, governments, and consumers alike operate similarly: threats are detected by comparing the code of programs and their activity with a database of "signatures" for known malware. Security companies such as F-Secure and McAfee constantly research reports of new malware and update their

$13 billion Amount invested by venture capitalists in the United States in the first half of 2012, according to PricewaterhouseCoopers and the National Venture Capital Association. It was $14.7 billion in the first half of 2011.

$4 billion The amount of the VC investment that went to software companies, up from $2.9 billion a year earlier. In the second quarter, VCs pumped more money into software companies than they had in any quarter since 2001.

lists of signatures accordingly. The result is supposed to be an impenetrable wall that keeps the bad guys out.

In recent years, however, attacks on governments and businesses have used software that, although not quite so sophisticated as Flame, also waltzed straight past signature-based software. Some experts and companies now say it's time to demote antivirus-style protection. "It's still an integral part [of malware defense], but it's not going to be the only thing," says Nicolas Christin, a researcher at Carnegie Mellon University. "We need to move away from trying to build Maginot Lines that look bulletproof but are actually easy to get around."

Christin and several security startups are working on new defense strategies to make attacks more difficult and to help those who are targeted fight back.

One example is CrowdStrike, a startup founded by veterans of the antivirus industry that has received $26 million in investment funding. Dmitri Alperovitch, CrowdStrike's chief technology officer and cofounder, says the company plans to offer a kind of intelligent warning system that can spot even completely novel attacks and trace their origins.

This approach is possible, says Alperovitch, because although an attacker could easily tweak the code of a virus like Flame to evade antivirus scanners, he or she would still have one goal: to access and extract valuable data. CrowdStrike understandably won't reveal details of its technology, but apparently it will analyze traces of activity on a customer's system to figure out if any of it could be from an infiltrator.

The idea is to thwart the most common tactics and make life harder for attackers, rather than focusing on the attackers' specific tools, which are "very changeable," Alperovitch says. "We need to focus on the shooter, not the gun."

Other companies are talking in similar terms. "It goes back to that law enforcement slogan 'Crime doesn't pay,'" says Sumit Agarwal, cofounder of Shape Security, another startup. The company has $6 million in funding from investors including Google chairman Eric Schmidt. Shape Security is also keeping quiet about its technology, but Agarwal will say that it aims to raise the cost of cyber assaults relative to the economic payoff, thus making them not worth the trouble to carry out.

Mykonos Software, too, aims to skew the economics of an attack. It has developed technology that helps protect websites by wasting hackers' time. Mykonos was bought by the networking company Juniper this year.

Alperovitch says his company will enable victims to fight back, within the bounds of the law, by identifying the source of attacks. "Hacking back would be illegal, but there are measures you can take against people benefiting from your data that raise the business costs of the attackers," he says. Those include asking the government to bring a case before the World Trade Organization and going public with what happened to shame perpetrators of industrial espionage, he says.

Research by Christin and other academics has shown that chokepoints do exist that could allow relatively simple legal action to neutralize cyber-crime operations. Christin and colleagues looked into scams that manipulate search results to promote illicit pharmacies and concluded that most could be stopped by clamping down on just a handful of services that redirect visitors from one Web page to another. And researchers at the University of California, San Diego, showed last year that income from most of the world's spam passes through just three banks.

But Agarwal warns that even retribution within the law can be ill-judged: "Imagine you're a large company and accidentally swim into the path of the Russian mafia. You can stir up a larger problem than you intended." —TOM SIMONITE

TO MARKET

Doctor on Wheels

RP-VITA

COMPANIES
InTouch Health and iRobot

PRICE
$4,000 to $6,000 per month

AVAILABILITY
Fourth quarter of 2012

Doctors who are away from the hospital can remotely control this robot and use it to videoconference with patients or medical colleagues. The RP-VITA (short for Remote Presence Virtual and Independent Telemedicine Assistant) can also call up patient medical records and display them to the remote doctor on an iPad or PC. Unlike earlier telepresence robots, this one doesn't have to be manually sent around the hospital by the remote doctor; it can be fed a map of a hospital's layout and instructed with a single click to go to a certain spot on its own, using sensors and obstacle-detection technology developed by iRobot.

COURTESY OF IROBOT

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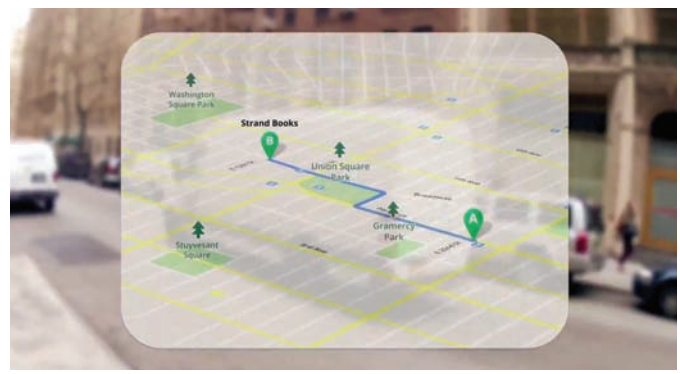
“This study suggests that you can potentially stop or slow down Alzheimer’s disease.”

—Kun Ping Lu, a physician scientist at Harvard, commenting on research from Weill Cornell Medical Center showing that a drug apparently halted cognitive decline and memory loss in Alzheimer’s patients

RANT

Signing Up for Google’s Glasses Is Like Asking for Problems

Are you prepared to manage the distractions inherent in a portal to the Internet that you can’t take your eyes off?



Someday, maps and other applications could come up in your field of view.

In the previous issue of this publication, Farhad Manjoo made a plausible case that Google’s new augmented-reality glasses, known as Project Glass, could make computing less distracting by replacing every other device in our pockets and laps. Rather than checking out of a conversation by looking down at our phones, we could get in and out of our computing environment without even turning our heads.

But here’s where human behavior comes in. We are really bad at ignoring distractions at hand. And the more accessible they are, the more addictive and distracting they can become. Let’s take all those distractions and put them on our face, directly in our line of sight? I don’t know about you, but when I want to avoid distractions, I often have to physically avoid them. “Out of sight, out of mind” isn’t just a cliché—it’s a commentary on the narrow spotlight of human attention and our inability to ignore something ever-present in our field of view.

Already, computers grab so much of our attention that savvy users deploy apps like SelfControl and Freedom, which switch off social media, e-mail, and other distractions. Certainly, we could use such aids on Google’s Glass. But I’ll bet most of us won’t.

Do you find it unnerving when the person next to you at the grocery store is having a conversation with himself or herself, and at first you don’t realize it’s because he or she is speaking into a phone headset? Google Glass is a camera, headphones, and a display all in one. So now imagine that the person in the grocery store seems to be having full-blown visual hallucinations.

Don’t get me wrong—I find the prospect of augmented reality tantalizing. I’m just not sure we yet know how to manage the ways it’s going to change our interpersonal relations.

—CHRISTOPHER MIMS

THREE QUESTIONS FOR

ROBIN DUNBAR

The anthropologist’s research has shaped business theory and social-network design.

1 You have posited that humans can maintain 150 stable relationships. How has the Internet changed this?
Apparently not at all. The 150 is just one layer in a series; beyond the 150 are at least two further layers (one at 500 and one at 1,500), which correspond to acquaintances and faces we recognize. When people add more than 150 friends on Facebook, they simply dip into these normal higher layers. Facebook has muddied the waters by calling them all friends, but really they are not.

2 Does this “Dunbar number” limit what Facebook can do?
I think its only practical effect is a PR one: you can’t sell Facebook as a way of widening your social circle. [That] happens very rarely—and it probably still requires you to get together in person to really create and cement the relationship. Facebook’s functionality seems to lie in its capacity to enable us to maintain friendships through time and over long distances where relationships would normally decay rapidly.

3 Could Web social networks negatively affect offline social behavior?
There are two possibilities. One is that time spent maintaining old friendships is time that can’t be spent creating new ones. Since friends exist to be shoulders to cry on (metaphorically speaking!) and shoulders that are physically remote aren’t much use for crying on, this might not be ideal. [Two], if your social experience is largely online, you may not be learning [face-to-face] social skills as well as you need to. —WILL KNIGHT

“There’s going to be graveyards full of buried battery companies.”

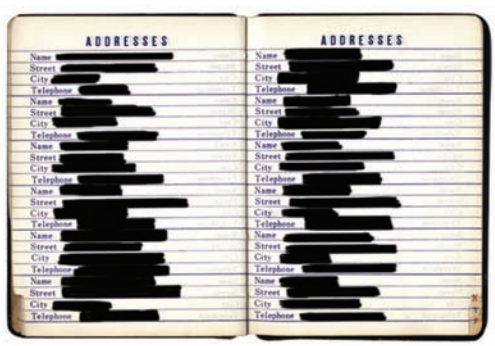
—Steven Visco, CEO of PolyPlus, a small battery company, predicting what will happen to startups that fail to partner with large manufacturers

COMPUTING

USE THEIR APP, KEEP YOUR DATA

A modified version of Android feeds data-snooping apps fake bookmarks and empty contact lists.

Many apps demand access to your contact lists, browser history, location, and other personal data, and it’s not always clear why they need it. To fight this data-gobbling trend, a Bulgarian software developer has rewritten the Android operating system so that it gives apps bogus data.



For example, when you click to grant an app permission to access your data, it doesn’t get your real bookmarks; instead, it gets the default ones that came with the device (such as www.google.com). When the app requests phone contacts and logs, which can store all sorts of data, it gets empty ones. “I don’t like applications accessing my location or phone book,” says the developer, Plamen Kosseff, who by day writes code in Sofia, Bulgaria, for ProSyst, a software company. “Why should they be accessing my phone book to see data I have from other people?”

Kosseff’s custom OS reflects a trend toward giving users more control over how apps deal with their personal data in the wake of revelations such as last year’s Carrier IQ controversy, in which an obscure piece of network-diagnostic software on 141 million phones was revealed to have the ability to transmit personal information.

NQ Mobile, a mobile security firm, recently released a mobile vault app, which turns part of your phone into a password-protected, encrypted storage space for sensitive data. Apps can access only the device’s default contact list, for example, not the one you’ve put in the “vault.” North Carolina State University computer scientist Xuxian Jiang and colleagues are working on an application, still in the research stages, that’s a little more nuanced than Kosseff’s. Called “taming information-stealing smartphone applications,” or TISSA, it gives users more control over the information that other apps can access.

The app would allow you to decide which information to share—like a phone’s unique ID number, contacts, and location. Then, for each type of data, you’d have four versions you could give an app: “trusted” (the actual information), “bogus,” “anonymized,” or simply “empty.”

“Basically, we could allow users to customize in a fine-grained manner what data will be available to a particular app,” Jiang says. “Maybe if you are in a sensitive conference meeting, you don’t want an app to see your location.”

The team’s application has not yet been deployed. To work, it needs control over other apps, which would require a change in the operating system—a task Jiang is hoping device makers will help with.

In the meantime, it falls to people like Kosseff to implement solutions. His Android revision works only for the HTC Desire HD phone for now, though he says that simple changes would make it work on Samsung devices and other Android phones. Kosseff says he is looking for other developers to help make that possible.

—DAVID TALBOT

JEN HALE; COURTESY OF ORASURE TECHNOLOGIES

TO MARKET

A No-Wait HIV Test

A Pennsylvania-based company is about to begin selling the first in-home HIV test. Users swab saliva from their mouth, and in 20 minutes, the OraQuick can detect HIV-specific proteins. It’s easier and faster than other over-the-counter HIV tests, which require people to mail a blood sample to a lab. Health officials hope such simple, private procedures will encourage more people to get tested for the virus that causes AIDS. The U.S. Centers for Disease Control estimates that 230,000 of the 1.1 million Americans with HIV don’t know they have it.

OraQuick Rapid Antibody Test

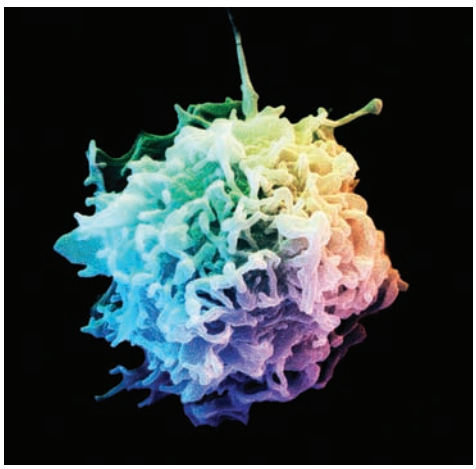
COMPANY
OraSure Technologies

PRICE
$17.50 for medical centers; consumer price not yet set.

AVAILABILITY October

“Banks need to be aware of what’s going on. There’s no point in trying to stop it or control it.”

—Aaron McPherson, practice director of IDC Financial Insights, explaining why big financial institutions are investing in startups that facilitate payments from smartphones



A colored scanning electron micrograph depicts a T cell.

BIOMEDICINE

T-cell Vaccines Could Treat Elusive Diseases

A biotech company is pursuing an approach that could redefine infectious medicine.

For some infectious diseases, traditional vaccines just don’t cut it. Microbes that hide inside human cells and cause chronic illness aren’t stymied by the antibody response generated by the kinds of vaccines available at the doctor’s office. T-cell vaccines, which activate a different type of immune response, could in theory offer a better way to prevent or control such infections, but so far nobody has been successful at bringing T-cell vaccines from the lab bench to the clinic.

Now Genocea, a biotech company in Cambridge, Massachusetts, thinks it can do it. It will test the claim this fall with its first clinical trial, on an experimental herpes vaccine.

All existing vaccines rouse the body into creating antibodies that attach to the surface of infecting microbes and flag them for destruction. But pathogens that live inside our cells, such as the viruses, bacteria, and other microbes that cause AIDS, malaria, herpes, and chlamydia, can evade this surveillance. “In order to deal with those types of pathogens, oftentimes we have to stimulate what we call cellular immunity,” says Genocea cofounder Darren Higgins, a Harvard biologist. “Unlike antibody immunity, which recognizes pathogens directly, cellular immunity has to recognize the infected cell and get rid of your own infected cells.”

It’s challenging to activate cellular immunity and the family of infection-fighting cells, known as T cells, that drive it. The trial-and-error method used to develop antibody-based vaccines has not worked for T-cell vaccines. Despite years of academic and industry work, and even clinical trials, there are no T-cell vaccines for infectious disease on the market. “We don’t know all of the rules yet—if it’s possible to make a T-cell vaccine, [or] how effective it would be,” says Robert Brunham of the University of British Columbia, who is developing a T-cell vaccine against chlamydia.

Indeed, our understanding of how T cells control infection is still developing. The challenge is to identify the pathogen protein that will grab a T cell’s attention and signal that a human cell harbors an infectious agent. “If you can figure out what those protein pieces are, then you can use those proteins as a vaccine to sort of educate your immune system on what to respond to,” says Higgins.

The challenge gets tougher with pathogens whose genomes encode more proteins. There are 80 or so proteins in the herpes simplex 2 genome, about 1,000 in chlamydia, and 5,000 or so in malaria. Genocea has a high-throughput screening method in which it collects as many of a pathogen’s proteins as can reasonably be produced in a lab and then monitors how human immune cells respond to each.

Although Genocea’s herpes vaccine is still unproven, the work is moving faster than typical vaccine research, which can take 10 years to go from discovery to proof of concept and 20 years to reach the market. —SUSAN YOUNG

TO MARKET

A Giant of Wind Power

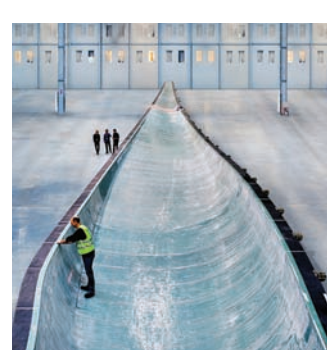
To boost the electricity that wind farms can generate, Siemens has developed what it calls the world’s longest rotor blades for wind turbines. The bigger the blade, the more wind energy it can capture; with three of these 75-meter blades, a single turbine can generate six megawatts of electricity. To make the blade this big without making it too heavy, Siemens produces it as a single piece of fiberglass-reinforced resin and balsa wood, without seams or joints. Intended for offshore wind farms, where winds are generally strong and steady, the blade will get its first test this fall at a power station off the coast of Denmark.

B75 Rotor Blades

COMPANY Siemens

PRICE Not disclosed

AVAILABILITY Now

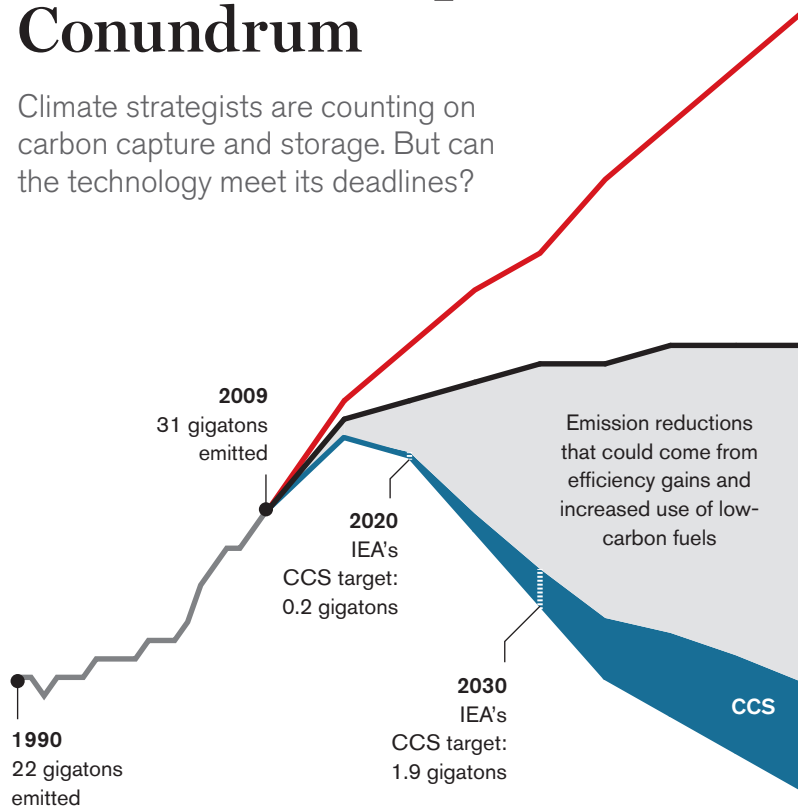


DAVID SCHARF/SCIENCE FACTION/CORBIS; COURTESY OF SIEMENS

graphiti

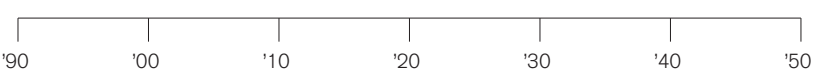
The Carbon Capture Conundrum

Climate strategists are counting on carbon capture and storage. But can the technology meet its deadlines?



Global CO_2 emissions and three projections for the future

Source: International Energy Agency

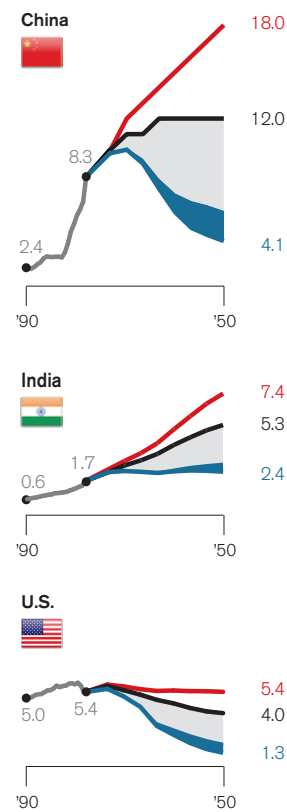


Current trajectory
58 gigatons
This projection assumes that essentially no action is taken to address climate change. Models predict a long-term global temperature rise of 6 °C in such a scenario.

Global pledges
40 gigatons
If countries make good on their pledges to reduce emissions, the projected trajectory is much less steep. Models suggest a long-term global temperature rise of 4 °C.

Target
16 gigatons
Models associate this trajectory with a long-term global temperature rise no higher than 2 °C. That has been a long-standing goal in climate change negotiations.

Scenarios and CCS targets for the three highest-emitting countries (in gigatons)



Many things will have to happen if we are to lower greenhouse-gas emissions enough by 2050 to avoid catastrophic climate change. One of those things, according to a number of projections, is the large-scale deployment of carbon capture and sequestration technology, or CCS. In this process, carbon dioxide emissions from such sources as fossil-fuel power plants and industrial facilities are collected, compressed, transported to a storage site, and injected deep underground for permanent storage.

Indeed, with demand for fossil fuels still soaring, the International Energy Agency predicts that one-fifth of the carbon dioxide reductions necessary by 2050 will have to come from CCS (shown in blue in the chart above).

The problem is that large-scale CCS is poorly understood and prohibitively expensive. As a result, there are not yet any facilities aimed at controlling power plant emissions. In the absence of government incentives, technology for injecting carbon dioxide underground is used mainly by oil companies as a way to extract hard-to-reach oil; these and other projects are injecting about 20 million metric tons of the gas annually. By the IEA's estimate, annual carbon dioxide sequestration will need to jump by a factor of about 15 by 2020 and 120 by 2030, and at least 110 more big CCS facilities must come online in the next eight years. Although 65 are in planning or construction phases, building one can take more than a decade. This problem might not be one we can bury. *—Mike Orcutt*

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q&a

Fred Wilson

The well-known investor behind the likes of Twitter and Foursquare says venture capital funds have gotten too big.

Fred Wilson, managing partner at Union Square Ventures, is a preëminent figure in venture capital. He's been at it for 25 years: his first big deal was an investment in the Web community GeoCities, which Yahoo bought for about $3 billion in 1999. He went on to back startups including Twitter, Zynga, and Foursquare. But from his successful perch, Wilson worries that his industry is in trouble.

Lately VCs haven't come close to generating the returns on their investments that made them stars in the 1990s. It's even becoming questionable what value they generate for society. IT companies are finding it cheaper than ever to get going now that they can rent computing resources from providers in the "cloud." Meanwhile, alternative funding mechanisms are proliferating. And because VCs often shy away from technologies that take a very long time to bear fruit, such as many in energy or biomedicine, some critics contend that VCs flood the world with too much money for ideas that don't solve big problems.

In a recent interview in his Manhattan office with *Technology Review* information technology editor Rachel Metz, Wilson offered some ideas for fixing venture capital.

_TR_: What is the biggest issue facing your industry right now?
I think a lot of venture capital firms are having a tough time raising money.

Why?
Because the returns haven't been very good in the venture capital industry for a long time. I think if you talk to the investors in venture capital partnerships, they'll tell you that they're very much on the fence on venture capital, and if venture capital continues to put up mediocre returns, they're not going to stick with it forever.

What is a mediocre return?
Anything less than three times your money over a 10-year period.

Why is venture capital necessary to foster technological innovation?
The reality is, venture capital has always been a place where high-risk ventures can get funded. I think it still is the best kind of capital for somebody who's building a company that has a lot of risk but has a lot of upside as well.

But it seems like the need for VCs is narrowing. These days, it's much cheaper to get an IT company off the ground. And there are more angel investors who get companies running before VCs can jump in.
There are a lot more places to go for money, which I think is a good thing for venture capital, because it allows more entrepreneurs to get going. We see more projects. There are more quality opportunities for us to invest in. At first blush, you might think that more capital means more competition. But I think what more capital really means is more entrepreneurs.

Some startups are getting money through crowd-funding platforms like Kickstarter (in which Union Square Ventures is an investor). Is this threatening to the venture capital model?
I think it's too soon to tell. Many of the projects that get funded on Kickstarter aren't really businesses. They're art projects, films … things like that. There's a small subset of projects that get funded [on Kickstarter] that could turn into companies. And some of them might actually become venture funded, and some of them might not need venture funding because they raised enough money with their Kickstarter project that they can get all the way they need to go without it.

Could part of the problem be that there's actually too much money available for entrepreneurs?
I don't think there's too much money sitting around. I think there's too much money in too few hands. So when six white guys in suits control two and a half billion dollars, that's not a good thing. Instead of being allocated just to one firm, it would be better if that two and a half billion dollars was allocated to 25 firms at $100 million each. It would lead to more diversity or people trying more things: data sciences, urban sciences, transportation, energy, materials science, and many others.

How do you fix a problem like that?
It's a challenging problem, because I think people who invest in venture capital like to go into deals together, and they like to invest in firms that have brand names and have long track records. That's what leads to a concentration of money in a few big-name firms. I think it's a little bit of how the system is just set up.

One of my hopes is that as there are more angel investors out there, and the amount of money it takes to make a company successful comes down, entrepreneurs are going to have more options. tr

JON O


“I DON’T THINK THERE’S TOO MUCH MONEY SITTING AROUND. THERE’S TOO MUCH MONEY IN TOO FEW HANDS.”

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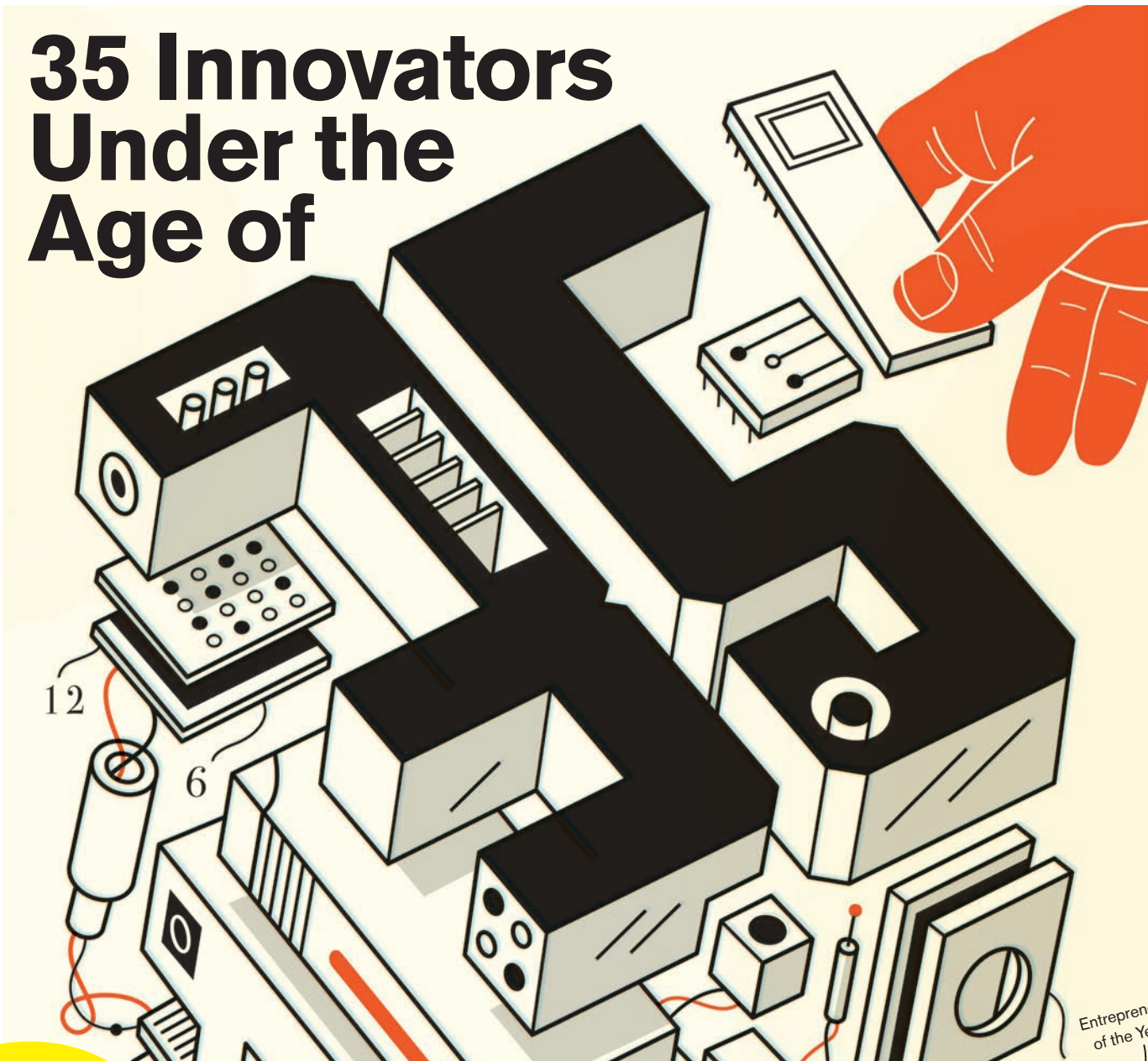
35 Innovators Under the Age of



Entrepreneur of the Year

Some members of our latest list of young innovators from around the world have developed consumer Web services you might have used, such as Spotify or Dropbox. Others are making more fundamental breakthroughs that have yet to be commercialized, such as more efficient engines or improvements in optical communications. And a few are blazing trails in fields that didn't exist before, like pop-up fabrication of tiny machines, or cameras that can see around corners. But all 35 of them have something significant in common: their work is likely to be influential for a very long time. We hope that these stories about them surprise and inspire you. *—The Editors*

To see the list of judges, videos with honorees, and previous young innovators: www.technologyreview.com/tr35

Illustration by Harry Campbell

Ng takes aim with the Lytro camera, which snaps photos that can later be refocused.

Photograph by Timothy Archibald

AGE: 32 **AFFILIATION:** Lytro

ENTREPRENEUR OF THE YEAR

REN NG

By tracking the direction of light, a camera takes pictures that can be refocused on different objects in a scene

Today's digital cameras do the focusing for you, but they occasionally blow the shot with a blurred subject. That's never a problem with Ren Ng's camera. His company, Lytro, sells a $399 model that captures light in a very different way from conventional cameras, recording the angle at which each ray enters the lens. The resulting photo can be sharply focused on any part of the scene, and then refocused on a different part—all long after the picture has been taken. "This is going to drive even larger transformations than the transition from film to digital photography," says Ng.

Ng's camera is at the leading edge of the new field of computational photography, which uses software to wring new tricks out of conventional optical components and a few novel ones. Lytro is preparing to release software upgrades that will allow shots taken with one of its cameras to be viewed in 3-D, and it is developing methods that could get professional-quality shots from cameras with cheap lenses, such as those on cell phones.

The focusing trick is an impressive enough start. When a photo taken with the Lytro camera is displayed on a computer, anyone can click on any object in the picture to get the software to instantly bring that object (and anything else in the photo that was the same distance from the camera) into sharp focus, leaving the rest artfully blurred. The focus point can then be changed with a click elsewhere in the photo. Friends can refocus Lytro photos for themselves when they are shared on Facebook or elsewhere online.

Whereas a conventional digital camera captures a focused image as light strikes a sensor chip, the Lytro camera has a plastic sheet of thousands of tiny lenses directly in front of its sensor. These lenses take rays that come into the camera at different angles and direct them to different points on the sensor. That leaves an unfocused image, but it doesn't matter—because Ng's software in the camera can use the information about the angle of the light rays to bring any part of the image into sharp focus.

In 2006 Ng was a PhD student at Stanford University studying the illumination of virtual objects. But he wanted to work on something with a more tangible impact, so he put off finishing his degree and started researching ideas for better camera designs. He wasn't sure how to proceed until one day he found himself staring in frustration at a poorly focused photo he had recently taken. "I thought, 'Does the camera have to focus before you take the shot?'" he recalls. He had a strong hunch the answer was no, and he immediately set out to prove it.

Once he hit on the idea for his camera system with multiple lenses inside, Ng started tearing apart and rejiggering conventional digital cameras to build prototypes. When he wasn't screwing together camera parts, he was networking to scrounge up the expertise, technology, and funding he needed. After about nine months, he finally found himself at his kitchen table assembling what he hoped would be his first fully functioning prototype capable of after-the-fact focus. It worked, and became the subject of Ng's prize-winning PhD thesis.

Ng decided to start a company based on the technology. The easier path would have been to license it to one of the established camera manufacturers, such as Nikon or Canon, rather than trying to take them on. But he feared that a big company would simply try to add the technology to its existing cameras as an incremental improvement. "A transformational technology requires a transformational product," he says. So he started Lytro, and after four years of stealthy development, the company's first camera began shipping in February.

Lytro has raised over $50 million in investments. It is currently working on introducing software to expand the capabilities of the existing camera model, with the 3-D upgrade expected this year. A bit further down the road, says Ng, could be cameras that will take refocusable videos. *—Tom Simonite*

PRASHANT JAIN

Tuning nanocrystals to make tinier, more efficient switches for optical computing and solar panels

AGE: 30
AFFILIATION: University of Illinois at Urbana-Champaign

Quantum dots are crystal particles, with a diameter of tens to thousands of atoms, that can absorb and emit different wavelengths of light or move electric charges around. Now Prashant Jain, a chemistry professor at the University of Illinois, has figured out a way to create tunable quantum dots that can be adjusted on the fly. His innovation could be key to designing optical computers and ultra-efficient solar panels.

Jain makes quantum dots out of copper sulfide, varying the ratio of copper atoms to sulfur atoms. At certain ratios, the amount and distribution of electrical charges inside the dots becomes sensitive to small changes in voltage—and it's that charge distribution that mostly determines the dots' properties, such as which wavelengths of light they'll absorb and emit. "You can controllably push and pull charges into these semiconductor nanocrystals and thus turn on and off their ability to interact with light," he explains.

That means the dots could function as submicroscopic optical switches—potentially, core components of an ultrafast optical computer that replaces electricity with beams of light. Jain's tunable-quantum-dot switch is about one-sixth the size of today's smallest transistors, and about a hundredth the size of current optical switches. Jain is also making quantum dots out of titanium oxide mixed with bismuth. These dots absorb solar light and convert it to electrochemical energy, which is used to generate hydrogen fuel from water.

Jain's dots are still very much in the research stage, and he predicts it will take an enormous amount of additional research to achieve practical optical computers or the super-efficient hydrogen production needed for energy applications. "There's a lot more fundamental work to be done," he says. *—Peter Fairley*

Vials hold some of the nanocrystals that Jain can manipulate with voltage to change their light-related properties.

JAIN LAB

JAIN SCULPTS THE FIELD OF LIGHT AT THE NANO-SCALE

Illustration by John Ritter

Ben Silbermann

A smartly designed social network for sharing images and interests

AGE: 30
AFFILIATION: Pinterest

Pinterest became a household name seemingly overnight in the spring of 2012. Founder Ben Silbermann had seen what other tech companies were overlooking: existing social networks, while letting users share information in just about any form, did not offer an emotionally warm and visually rewarding experience tied to individual passions. Guided by this conviction and his interest in collecting things, Silbermann directed his engineers—he's no programmer—to create a site that did.

Users of Pinterest create and curate virtual boards of photos clipped from websites and other users' boards, gathering up shots of lusted-after products and other stimulating images. When you log in, you're presented with a grid of new content that past activity suggests you might want to "pin" to your own boards. Silbermann describes it as a more interactive and social version of the lifestyle section of a newsstand: a place to find visually interesting, emotionally resonant content related to stuff you love—and often want to buy.

That vision initially gained momentum not at the elite colleges and California coffee shops that often function as the Web's proving ground for new ideas but by word of mouth in Silbermann's home state of Iowa. Perhaps as a result, Pinterest is big with the mainstream audience that other Web companies struggle to attract after they've conquered Silicon Valley. It's used by 34 million people worldwide each month, mostly in the United States. Google's DoubleClick advertising unit estimates that 79 percent of them are female.

Silbermann refined the idea for two mostly unpromising years after he talked a few friends into starting the company, running it from his own apartment until he received his first significant backing from investors in the summer of 2011. Though he initially had no users to offer feedback, he sweated countless details, having his lone designer, cofounder Evan Sharp, create 50 fully functional versions of the site's basic layout that varied spacing and image sizes by just fractions of an inch. Silbermann personally wrote to the first few thousand users to gather their impressions.

Now with over 60 employees and a spacious office in San Francisco, Pinterest has received a total of $138 million in venture capital funding; in the last cash injection, the company was valued at $1.5 billion. Silbermann says he's focused on improving the product rather than figuring out how to make money on it. But retail brands are discovering that they can use Pinterest to boost sales by encouraging people to share images of their products on what are essentially eye-catching shopping wish lists. And that would seem to leave the company well positioned to start charging brands for the privilege. There's a lot of value in, as Silbermann puts it, "helping people to discover things that they didn't know they wanted." *—Tom Simonite*

Illustration by Michael Gillette

BOZHI TIAN

Artificial tissue that can monitor and improve health down to the level of individual cells

AGE: 32
AFFILIATION: University of Chicago

"Cyborg tissue could allow us to put multifunctional prosthetics in humans," says Bozhi Tian. That goal is still a long way off, but Tian has taken a key step by creating artificially grown tissue that's intelligent. So far, he's developed a synthetic blood vessel that can detect the pH of solutions flowing through it. And with different nanoelectric sensors embedded in that and other tissue replacements, Tian thinks, the technology could one day wirelessly monitor proteins linked to cancer and other diseases.

Tian's cyborg tissue project grew out of another impressive feat: an innovative method for detecting electrical changes in living cells. Instead of sticking fine-tipped glass pipettes into the cells, a conventional technique that ends up killing them within a few hours at most, Tian created a semiconductor device made of a kinked nanowire less than 50 nanometers wide at the tip.

He then coated the tip of his probe with molecules similar to those found in cell membranes, enabling the device to enter the cell with minimal damage. The implanted nanowires can potentially send information for days, and cells can tolerate multiple wires, making it possible to map complex changes across the cell.

By coating the wire with antibodies, which can be designed to latch onto a specific molecule, researchers could enable the tool to detect the presence of specific proteins seen when a particular disease state is getting better or worse. That could be useful for monitoring how cells respond to different compounds being considered for use as drugs.

Tian, an assistant professor at the University of Chicago, is currently working on equipping cells with electronic components that don't merely monitor activity but actively affect it. Get ready for the cyborg cell. *—Susan Young*

BLURRING LINES BETWEEN BIOLOGY AND ELECTRONICS

Pulling medical tape off newborn babies in hospitals can be extremely painful and even potentially dangerous. To find something safer, Bryan Laulicht, a postdoctoral fellow at Harvard University and MIT, tested dozens of adhesive materials commonly used in medicine. He soon discovered that the adhesives fell into two groups: those that stuck securely and those that could be removed painlessly. None of them met both criteria.

But Laulicht knew that evolution had long since solved the problem. The feet of the gecko, for example, sport pads that adhere strongly to surfaces for climbing, but when rotated in a certain way, the pads release easily so the animal can run. Convinced that an artificial material ought to be able to do the same, Laulicht hunted for a way to fabricate it.

Using existing adhesives and a new quick-release backing layer, Laulicht developed a dry adhesive, suitable for bandages and medical tape, that was inspired by the gecko's feet. Though he won't give more details before the results are published, he says that he and colleagues are gearing up to test his creation on humans.

Newborns are the immediate intended beneficiaries of the adhesive technology, but Laulicht says elderly patients and others with sensitive or injured skin need it, too. Because the adhesive is based mostly on materials found in existing types of tape, he hopes his bandage will find its way to the clinic quickly.

—Courtney Humphries

Laulicht holds a prototype of his high-stick, easy-release bandage, inspired by the gecko's foot.

Photograph by Christopher Churchill

BRYAN LAULICHT

Finding an adhesive that protects vulnerable skin

AGE: 31

AFFILIATION: Harvard University and MIT

Rana el Kaliouby

Teaching devices to tell a frown from a smile

AGE: 34
AFFILIATION: Affectiva

El Kaliouby's technology helps computers distinguish the varied faces that people make.

Photographs by Webb Chappell

Computers are good with information—but oblivious to our feelings. That's a real shortcoming, believes MIT Media Lab scientist Rana el Kaliouby, because it leaves them unable to usefully respond to many of our needs until we take the trouble to tap out instructions. To close that gap, el Kaliouby has come up with technologies that help computers recognize facial expressions and other physical indicators of how someone is feeling. Someday this could help make our machines more adept at assisting us.

El Kaliouby is not the first researcher to try to map facial expressions. But where others have focused on trying to get computers to recognize a half-dozen exaggerated expressions recorded in the lab, she is identifying the more varied and subtle faces that people commonly make. "It's a problem that requires pushing the state of the art of computer vision and machine learning," she says.

To break the problem down, she zeroed in on 24 "landmarks" on the face. Then she trained a computer to identify how those parts of the face change shape in response to different emotions, creating expressions such as a furrowed brow. To ensure that the technology would work with people in different cultures, el Kaliouby, who lives in Cairo and spends one week a month at MIT, enlisted the help of thousands of people on six continents. They have allowed their computers' embedded cameras to record their expressions while they watch a video, resulting in what she says is the largest database of facial images in the world.

One early experimental application of the technology was a set of camera-equipped glasses intended for people with Asperger's syndrome, who tend to have difficulty recognizing others' emotional states. The device could recognize whether someone facing the wearer appeared bored; if so, it could use small lights in the glasses to signal that to the wearer. (El Kaliouby herself was known to sport a head-cam in and out of the lab, tucked into the head scarf she wears.)

El Kaliouby has cofounded a company called Affectiva in Waltham, Massachusetts, to commercialize the facial recognition technology and a wristband that she helped develop to measure skin conductance, which is associated with emotional arousal and can be used to detect anxiety in real time. For now, Affectiva uses facial recognition mainly to give advertisers a better sense of how their ads are affecting viewers. The company convenes enormous virtual focus groups made up of online viewers who allow their expressions to be tracked, and then analyzes the resulting data. But in the longer term, el Kaliouby also wants to bring her technology to classrooms to help teachers identify which material students respond to best.

The technology could eventually become a critical component of many electronic devices, making it possible for them to recognize when we're puzzled, frustrated, happy, or sad—and enabling them to respond with the right information, music, or human assistance. And there's a lot to be said for getting our phones, PCs, and GPS systems to recognize when we just want to be left alone. *—Karen Weintraub*

WILLIAM CHUEH

Pulling hydrogen out of water with the help of concentrated sunlight and an inexpensive material

AGE: 29
AFFILIATION: Stanford University

While doing his doctoral studies at Caltech, William Chueh showed that heat from the sun can turn cerium oxide—a relatively cheap material—into an effective catalyst for splitting water to yield hydrogen that can be used to make fuel. Most other hydrogen extraction processes rely on expensive catalysts made from precious metals such as platinum. "There's simply not enough of those metals to make a dent in our fuel needs," says Chueh, who is now a materials scientist at Stanford University.

His process relies on mirrors of the type that some solar plants use to concentrate sunlight by a factor of 1,500. The sunlight heats the cerium oxide to 1,500 °C, driving out its oxygen. As the cerium oxide cools, steam is fed to it, which then gives up its oxygen to the oxygen-starved material, freeing hydrogen gas. The hydrogen can be collected, and the cerium oxide can be reheated to repeat the process.

Chueh has used the same process to split carbon dioxide. The resulting carbon monoxide can be combined with the generated hydrogen to make hydrocarbon fuel such as methane—a renewable alternative to extracting it from the earth. The technique generates about 100 times more carbon monoxide than previous processes for a given amount of energy.

Chueh's idea is to use his catalyst in combination with the type of large solar concentrators now used in power generation. Meanwhile, he's working to make cerium oxide–based hydrogen generation work at lower temperatures, because the only containers that can hold the material at 1,500 °C without melting are made of exotic alloys that cost too much. He's already developed a hybrid of cerium oxide and another material that shows the potential to work at 500 °C, which would allow the use of stainless-steel vessels.

—Peter Fairley

TRYING TO MAKE A DENT IN OUR FUEL NEEDS WITH THE SUN

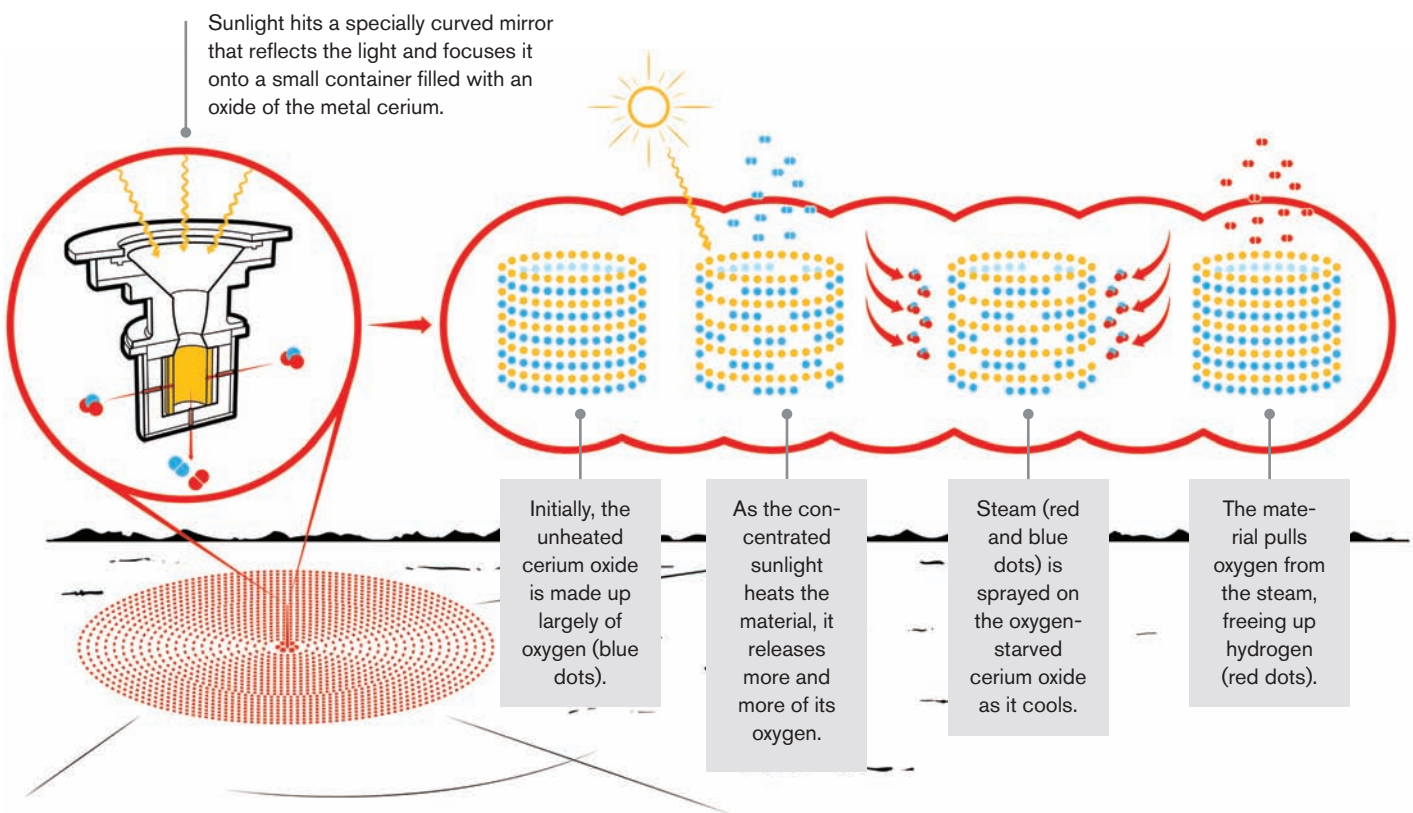


Illustration by MCKIBILLO

CHRISTOPHER SOGHOIAN

AGE: 30
AFFILIATION: American Civil Liberties Union

On a tear against bad privacy practices online, he urges companies to change the way they operate—and sounds alarms if they don't.

Christopher Soghoian sniffs out security holes and privacy shortcomings on the Web. Then he urges companies that are responsible—Google, AT&T, and Dropbox have been among them—to halt practices that put consumers' personal information at risk. If they don't, he'll write about the flaws publicly and try to get regulators to crack down. "I see myself as a combination horse whisperer and Paul Revere–type character," he says.

Soghoian's credentials as a computer scientist are substantial—he helped develop the Do Not Track mechanism that lets people prevent websites from following their online activity—but most of his work relies on techniques that suggest Woodward and Bernstein more than a basement hacker: he seeks information by filing Freedom of Information Act requests or cajoling corporate lawyers and congressional aides over late-night beers in Washington, D.C.

Insinuating himself into the world of Washington as a privacy gadfly didn't come easily to Soghoian, 30, an earnest geek with a beard and a ponytail. "I didn't own a suit until 2009," he says. Wearing one to face executives and lawyers is "not pleasant," he adds. But he has learned that his impact as a security researcher is much greater if he steps into power corridors and directly addresses the people there.

That lesson began in 2006. Soghoian, then a grad student at Indiana University, wrote a blog post about how easily someone could gin up a legitimate-appearing boarding pass to get past airport security checkpoints. To prove the point, he put a widget on his blog that made it possible for people to create their own. That inflamed the Homeland Security apparatus, and the FBI seized his computers for a month. When the furor subsided, a few rational officials in Washington pointed out that Soghoian was actually helping the Transportation Security Administration by identifying a flaw in its defenses. The episode taught him that if he framed his message in the right way, he could get people to listen.

In 2009, while working as a student fellow at Harvard's Berkman Center for Internet and Society, Soghoian led an effort to get Google to turn on SSL encryption in Gmail by default. SSL, the technique used to secure banking and e-commerce websites, essentially ensures that people using Gmail in a public Wi-Fi café aren't vulnerable to having their accounts plundered by criminals. After Soghoian and 36 cosigners wrote an open letter to then-CEO Eric Schmidt, Google eventually said it would indeed turn on SSL by default. This doesn't make Gmail totally private: law enforcement can still subpoena Google for an unencrypted look at the contents. But it does ensure that political dissidents' e-mail is out of the reach of repressive governments with which Google doesn't coöperate. Because of that, "if I'm 5 percent responsible for Google turning on SSL, it's the most important thing I've done in my life," Soghoian says. Today he's lobbying for SSL to become the default setting on other online services, notably Facebook. (Facebook spokesman Frederic Wolens says the company is working on it; in the meantime, SSL is available to Facebook users who activate it themselves.)

In 2009, Soghoian stepped a bit too far into the establishment for his comfort: he became a staff technologist for the U.S. Federal Trade Commission. In October of that year, he went to a telecom-industry event and recorded a Sprint Nextel executive explaining how often the company fed data about subscribers to law enforcement. To him, this is a crucial subject—his recently completed PhD dissertation is all about the ways that police get around outdated wiretapping laws by having telecommunications and Web companies do surveillance for them. He argues that these companies, without sufficient public recognition, have effectively replaced judges as arbiters of whether the authorities are acting appropriately. But that's not entirely in the FTC's purview—and in any case, Soghoian had made the secret recording after using his FTC badge to get into the closed event. He ultimately lost his job.

Now he's probably found a more natural outlet for his work: in September he will become a principal technologist and senior policy analyst for the American Civil Liberties Union, where he plans to keep raising alarms about how easily law enforcement, spies, and criminals can delve into our ever-growing storehouses of personal data. "My goal," he says, "is to move to a world where everybody has access to secure communication." *—Brian Bergstein*

Soghoian is a computer scientist turned privacy watchdog.

Photograph by M. Scott Brauer

Illustration by John Ritter

BAILE ZHANG

A new type of invisibility cloak made from a common material can work with larger objects

AGE: 31
AFFILIATION: Nanyang Technological University, Singapore

There's been a lot of excitement, both in the scientific community and in the popular media, about the possibility of creating cloaking materials that make people or military vehicles appear to vanish. But that goal seemed nearly impossible until Baile Zhang came up with a simple, promising solution. While Zhang's technique has serious limitations—for one thing, it works only in an exotic medium called laser oil—it does suggest a possible path to making practical invisibility cloaks.

Most previously developed invisibility cloaks were made with materials painstakingly fabricated in the lab to have micro- or nanoscale patterns that bend light waves. But labs couldn't turn out more than tiny amounts of these materials. What's more, most existing examples of cloaking materials work only with microwaves and other nonvisible forms of light.

Reading about these exotic materials, Zhang, a professor at the Nanyang Technological University in Singapore, remembered a high-school physics demonstration of how calcite, an inexpensive natural mineral, bends light in strange ways. That, in turn, led him to come up with a simpler way to make a large cloak: gluing two pieces of calcite together.

Zhang demonstrated that his calcite sandwich could hide the middle section of a Post-it note rolled into a tube and placed on a mirror submerged in a liquid. The calcite cloak on top of the tube guides light from the space behind the tube to a point directly over it, so that the eye is, in effect, seeing right "through" the rolled-up paper. It turns out calcite's crystal structure already resembles the sorts of artificial nanoscale patterns that other labs have been struggling to fabricate with electron beams.

"This shows better than any other experiment that the basic concept of cloaking can work," says Steven Cummer, an engineering professor at Duke University, who was on the team that made the first cloaking device. But Cummer cautions that Zhang has a lot of work ahead to make this simple cloak more practical.

Right now the calcite trick works only if the medium around it helps to bend the light, which means the medium has to have just the right refractive index. The bath of laser oil used for the initial demonstration did the trick, but water or air won't work.

Zhang is hoping, however, that some new tricks he has in mind will allow the cloak to work in air. That's a project worth keeping an eye on.

—Katherine Bourzac

THE PROCESS IS AS EFFICIENT AS THE BEST BATTERIES

Danielle Fong

Making clean energy pay off by storing it as squeezed air

AGE: 24
AFFILIATION: LightSail Energy

A stumbling block to increasing our reliance on electricity from cleaner energy sources such as solar panels and wind farms has always been figuring out how to efficiently store the energy for use when the wind isn't blowing and the sun isn't shining. Danielle Fong could make clean energy significantly more practical on a large scale by introducing a novel way to use tanks of compressed air for energy storage. "It could radically reorient the economics of renewable energy," she says.

The idea of using compressed air to store energy is not new. Electricity from solar panels or wind turbines can turn a motor that's used to compress the air in a large tank, and the air pressure can then be converted into power to drive a generator when the power is needed. The problem is that during compression the air reaches temperatures of almost 1,000 °C. That means energy is lost in the form of heat, and storage in conventional steel vessels becomes impractical.

Fong stumbled on a possible solution while skimming through a nearly century-old book: spray water into the air while compressing it, creating a fog that doesn't get as hot. To make the process practical, she developed a technique for separating the heated water from the compressed air and diverting the water into a tank, so the heat can be recaptured to minimize energy loss. The process is about as efficient as the best batteries: for every 10 kilowatt-hours of electricity that goes into the system, seven kilowatt-hours can be used when needed.

Fong founded a company called LightSail Energy in Berkeley, California, to develop the technology. Initially, she planned to produce compressed-air-powered scooters. But backer Vinod Khosla of the venture capital firm Khosla Ventures convinced her to go after the much bigger market of electricity for the power grid.

Batteries are the current state of the art in storing excess wind and solar energy, but Fong says the LightSail system will cost less to purchase and will last for a decade or more. Over the long term, she says, the system could cost as little as a 10th as much to own and operate as batteries do. A single system, which is about the size of a shipping container plus a car-size unit, will store the energy generated by a one-megawatt wind turbine running for three hours.

Fong and the LightSail team had to come up with a filtering system capable of separating the water from the highly compressed air. Another challenge was to design a system that could handle both compressing the air and expanding it to drive a generator; previous efforts have required two separate systems.

Not only did LightSail meet those challenges, but it managed to find a compound—the company won't provide details—that can be used more efficiently than steel to make compressed-air storage tanks. Tanks made from this material also don't need the costly underground installation that's normally required. And unlike standard systems, LightSail's doesn't need the turbine to run at a fairly constant speed to get efficient compression, meaning it is better able to cope with intermittent wind conditions.

Fong says there are no technical barriers to building units large enough to power entire cities. The company plans to manufacture the systems, and she says several renewable-energy developers have already signed on as customers. The first pilot unit is scheduled to ship in late 2013 or 2014—but she is still hoping to see those compressed-air scooters.

—Rachel Metz

JOHN HERING

Securing our smartphones from spyware and rogue apps, with a little help from the crowds

AGE: 29

AFFILIATION: Lookout Mobile Security

Hering's company, Lookout, helps keep malware off your phone.

Photograph by Timothy Archibald

In 2005 John Hering notoriously invented a hacking "rifle" called the BlueSniper that enabled him to take control of a Nokia handset from a record-setting distance of 1.2 miles. But though he's been a hacker since childhood, Hering isn't the kind of hacker you have to worry about. In fact, his mission is to keep your cell phone safe from malware.

The BlueSniper stunt was all about exposing security weaknesses in Bluetooth technology. Hering used the attention he got from it to further a more ambitious idea: that there should be a central database of information about phone malware. In 2007 he cofounded Lookout Mobile Security with two college buddies and created a free app that protects Android users from malicious apps—say, a fake version of a game that tacks an easy-to-miss $5 charge onto your monthly smartphone bill. Lookout found 1,000 instances of virus-infected apps last year and found that Android users had a 4 percent chance of encountering malware, a number expected to rise.

To stay on top of the bad guys, Lookout has built what it calls the Mobile Threat Network: a giant database, tallying more than a million rogue apps, that it continuously adds to as the company's software scans and analyzes apps worldwide. When an Android smartphone owner uses Lookout's app, it compares installed apps against its database of known threats and notifies the user when it detects a match.

Users can help by allowing Lookout to collect data from their mobile devices, essentially crowdsourcing the job of finding threats. That approach to identifying malware stands in contrast to the methods used by traditional security software for desktop computers, which rely on professionals working in the background to find threats in the digital wild.

Last year, Lookout blocked millions of mobile threats, according to the company. More than 20 million people have downloaded the app. (Most of Lookout's revenue comes from users who pay $3 a month to subscribe to a premium service that also secures mobile devices' Web browsers and makes it possible to lock or erase stolen phones remotely. But Hering won't say whether the privately held company is profitable yet.)

Hering says he thinks of his approach to mobile security as one that will empower users, not hamper them, as desktop security programs sometimes do. "Security is typically something that's thought of as a burden," he says. "It slows down your computer, it tries to scare you. It's all these things that we don't stand for." *—Rachel Metz*

Illustration by Michael Gillette

JOYCE POON

A tiny roller coaster for light could help keep data centers cool

AGE: 32
AFFILIATION: University of Toronto

Optical communications could be a boon for data centers, reducing electricity use and heat buildup by replacing electronic signals with light signals. But the technology has been cost-effective only over distances of a kilometer or more, and using it in data centers would mean sending signals mere meters or centimeters. Joyce Poon may have solved the problem by creating new optical modulators with microscopic loop-the-loops through which light can shuttle data between servers and even from chip to chip within a single server.

To make light-based data communications work over short distances, Poon, an assistant professor of electrical and computer engineering at the University of Toronto, knew she needed to come up with a much smaller version of an optical modulator, a device that converts an electronic signal into an optical one. She designed tiny rings that can be built onto computer chips. When laser light is sent into a ring, it races around the ring over and over before a bit of it emerges through a waveguide at the bottom. The trick was to control how much light came out. Other researchers working with micro-rings have tried to do that by adjusting the properties of the ring, in order to alter the length of the light's path or the amount of light the ring absorbs. Poon realized she could leave the ring alone and simply control the gateway between the ring and the rest of the chip.

The resulting optical modulator can be both faster and more efficient. With a team from IBM, Poon is working to create a version that is competitive with today's optical data rates.

The jump to optical data transmission in servers can't come soon enough. Data centers consumed at least 200 billion kilowatt-hours' worth of power in 2010, and the proliferation of smartphones and cloud storage is only going to push that higher, driving up costs and the risk of heat-related outages. *—Neil Savage*

LIGHT CAN SEND DATA FROM CHIP TO CHIP

GLASS COULD CHANGE AT THE FLIP OF A SWITCH

SARBAJIT BANERJEE

Windows that block heat—but let it through when you want them to

AGE: 33

AFFILIATION: University at Buffalo, State University of New York

Is there a way for a window to reflect heat in the summer and let it through in the winter?

A window that changed in response to the heat might behave in just that way. Sarbajit Banerjee, a materials chemist at the University at Buffalo in New York, is applying his work on a compound called vanadium oxide to coat glass with a material that makes this possible.

Banerjee had been studying vanadium oxide because he was interested in the physics of phase transition—for example, the way water freezes as the temperature drops. When the temperature reaches 153 °F, this compound's crystalline structure changes from one that's transparent to infrared light—that is, radiated heat—to one that reflects the light.

Using nanofabrication techniques to change the microscopic structure of the crystalline material, Banerjee found a way to lower the temperature at which that change occurs. When the material is formed as long, thin nanowires, it undergoes the transition at a mere 90 °F. A researcher at a window company suggested that this version had good characteristics for a switchable window coating.

Banerjee was able to bring that temperature down even further by mixing tungsten into the material. And perhaps most promising of all, he found that he could trigger the transition at a range of temperatures by sending an electric current through the material—holding out the promise of changing a room's temperature with the flip of a switch, and without racking up an energy bill.

Banerjee is now in the process of licensing his heat-blocking window coating to a U.S. building-materials company; he predicts that it will cost just 50 cents per square foot. He also has a partnership with Tata Steel, a global manufacturer headquartered in Mumbai, India, and they are looking at how to use the material to deflect heat from the corrugated-steel roofs that commonly turn houses stifling in India and other parts of the developing world.

—Katherine Bourzac

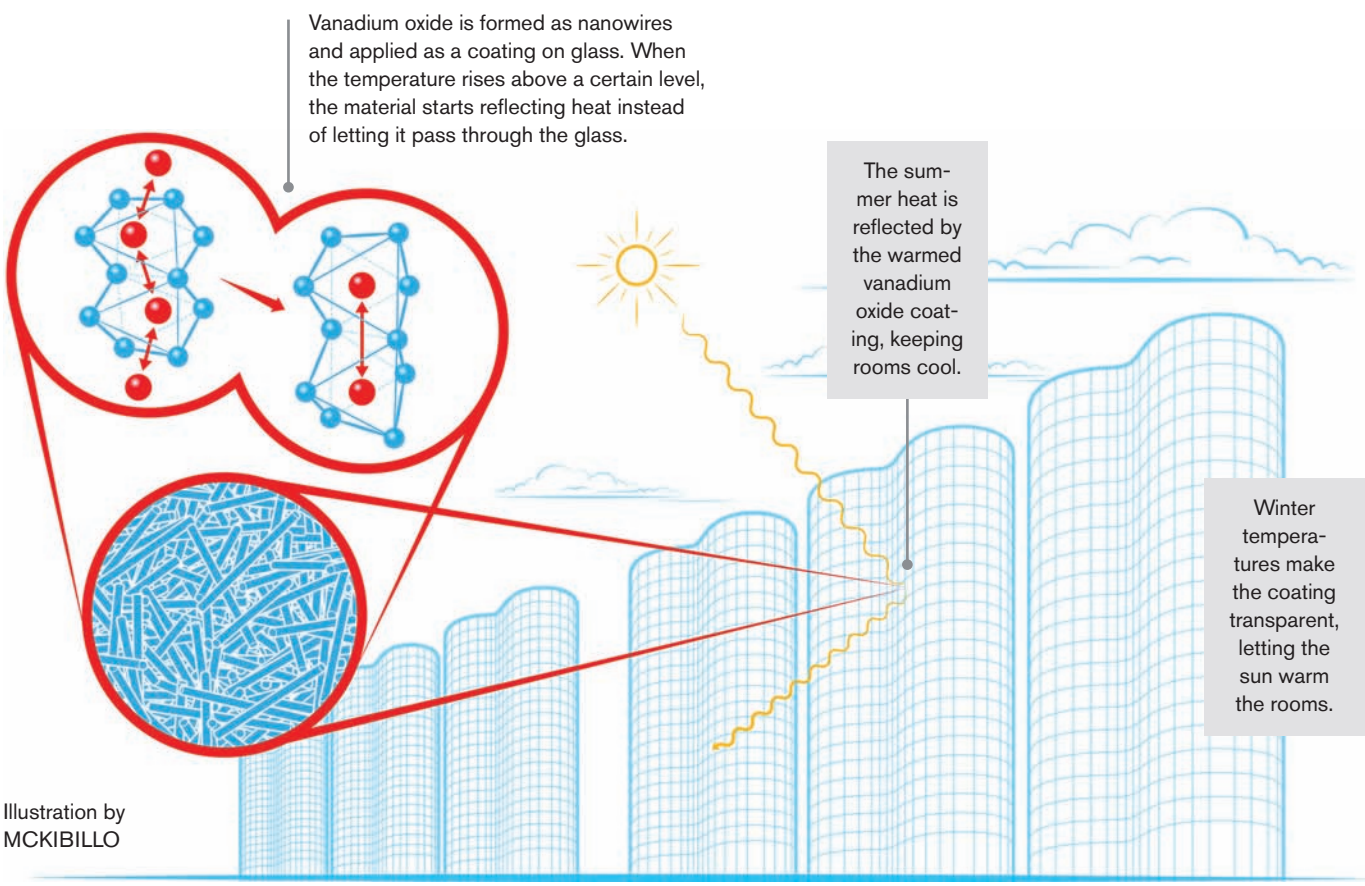


Illustration by MCKIBILLO

Miller's high-compression engine generates electricity as efficiently as big power plants.

Photograph by Timothy Archibald

SHANNON MILLER

Making engines super-efficient by getting them to run at extremely high pressures

AGE: 33
AFFILIATION: EtaGen

It's hard to radically improve the internal-combustion engine. But Shannon Miller may have done it, by getting one to work at extremely high compression and expansion ratios. Initially designed to generate electricity in homes or businesses, not to power cars, Miller's engines use 25 percent less fuel than conventional gas-powered generators.

Miller knew that operating engines at high compression and expansion ratios could make them far more efficient, but that's easier said than done. High compression ratios create extreme temperatures, wasting energy. And high pressure increases friction between the piston and the cylinder.

So she turned to a "free-piston" design, an old idea that allows each piston to bounce

A PLAN TO "CHANGE THE WHOLE ARCHITECTURE OF THE ENGINE"

up and down independently of any rod or crankshaft. The approach had not been used to operate pistons at very high compression ratios. "To make this work, you can't just change one or two things," she says. "You really need to change the whole architecture of the engine."

Miller cofounded and is CEO of a company called EtaGen, which aims to bring the engine to market. The company has built a prototype that runs for hours at target performance levels. She says the results indicate that upcoming versions of the engine should be about as efficient as large power plants—the current gold standard for energy efficiency—once the energy the plants lose during distribution is factored in.

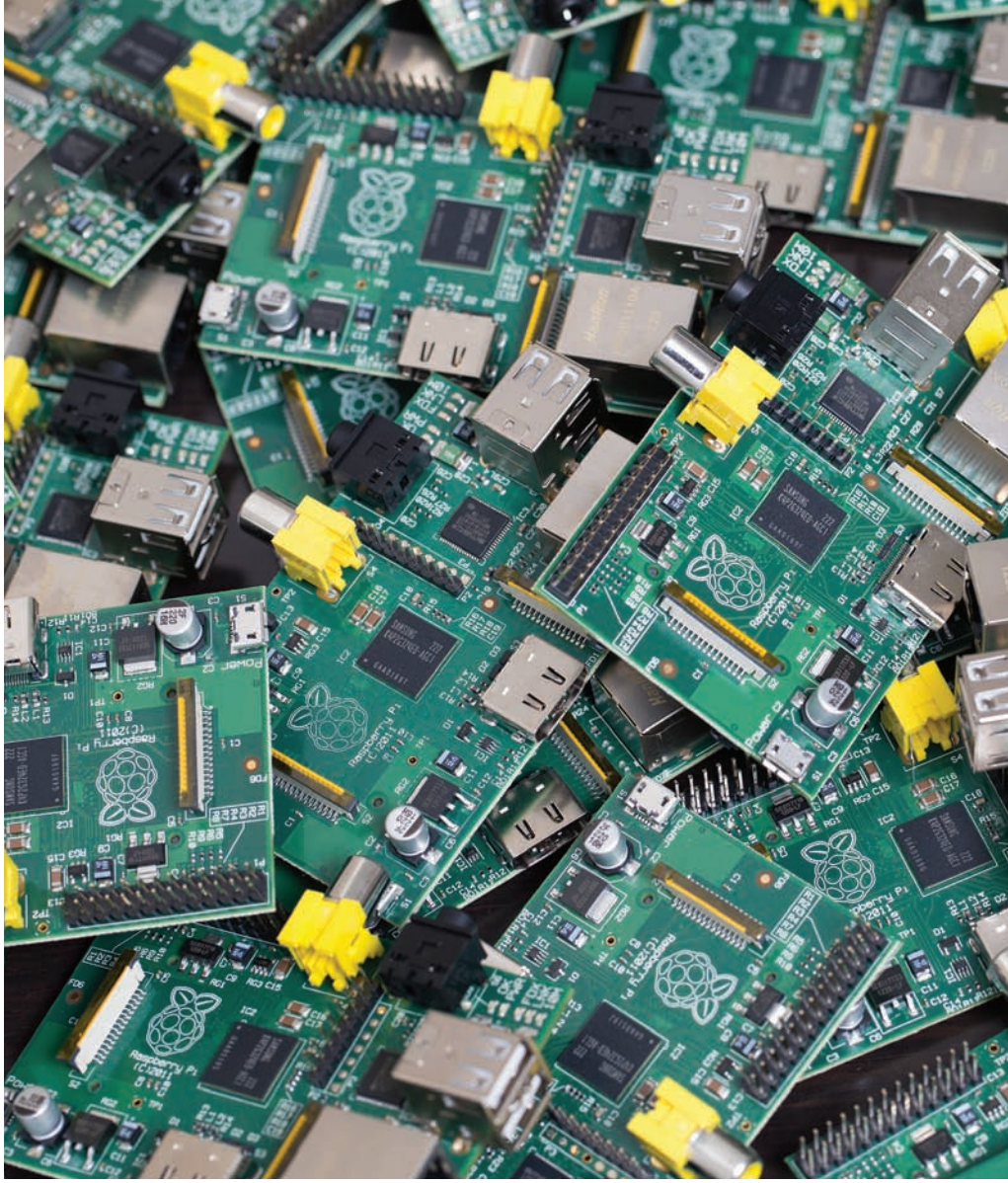
EtaGen's first product will be a replacement for conventional diesel and natural-gas generators, allowing businesses to operate a building off the grid or to ride through power outages. Eventually, Miller says, the same basic engine design could be used to make onboard generators for electric cars like GM's Volt. In either case, the engines would run on common fuels like diesel and natural gas.

—Kevin Bullis

AGE: 34
AFFILIATION: Broadcom

EBEN UPTON

His ultracheap computer is perfect for tinkering



Eben Upton thought a new generation of youngsters might never develop valuable hardware and software hacking skills unless they had access to cheap, hobbyist-friendly computers. So he set out to build one himself. The resulting tiny box, which sells for just $25, has been a big hit. It could boost computer skills not only among children but among adults in poor countries as well.

Upton came up with the idea in 2006, when he was finishing his PhD in computer science at the University of Cambridge. Having agreed to help out with undergraduate computer science admissions, he was looking forward to interacting with teenagers who loved messing around with computers as much as he had when he was younger.

Upton had done all that messing around partly for the thrill of bending the machines to his will, and partly because the 1980s boom in video games had made it easy to imagine making a fortune working with computers. "I was a mercenary child," he says, sounding a bit apologetic. "One of the things that drew me to computing was that there were 15-year-old kids who made so much money from computing they actually bought Ferraris."

To judge by the applicants Upton was looking at, however, kids had lost interest. They were still messing around *on* computers, but they weren't messing around *with* them. They weren't writing programs and taking apart circuit boards. They were the kinds of kids who played World of Warcraft and exchanged cat pictures on Facebook. They had changed from active hackers to passive consumers.

Perhaps the dot-com bust had killed some of the enthusiasm for hacking. But to Upton, one other possible factor loomed large. In the 1980s, he and his friends had learned basic computer science on a BBC Micro, a line of computers built for the British Broadcasting Corporation by Acorn Computers and installed in most English schools. Small, rugged, inexpensive, and expandable, the Micro introduced a generation of British children to hardware engineering and software programming.

There was no contemporary equivalent to the Micro. "Sure, everyone in the middle class has a PC," Upton says. "But even then, often there is only the one family PC. You won't let kids screw around with it." Schools aren't going to let students take apart their machines, either. As a result, he observes,

Caseless and ungainly, Raspberry Pi computers are cheap and simple enough to mess around with.

Photograph by Alex Tehrani

"computing" classes teach children how to use Microsoft Word and PowerPoint. "Even Microsoft wants schools to produce software engineers," Upton says. To successfully restore literacy in computer tinkering, he decided, the world needed a modern analogue of the BBC Micro.

Being a hardware guy at heart, Upton went ahead and built a prototype of a next-generation hobbyist machine—the sort of stripped-down device that would enable its users to become acquainted with the guts of a computer. It would also allow its users to put the machine to work in projects ranging from robotics to wearable computing to gaming. He eventually took up a Cambridge professor's suggestion to call his device Raspberry Pi, tipping his hat to the old tech tradition of naming computers after fruit. But he didn't immediately see a way to produce Raspberry Pi in sufficient numbers to make a difference, so he reluctantly mothballed the project.

After finishing his PhD, Upton went to work at the Cambridge, U.K., office of Broadcom, a networking company based in Southern California. (He is now one of the company's technical directors for Europe.) Upton was instrumental in the creation of Broadcom's first microprocessor intended for multimedia applications—the BCM2835. Released in 2011, it is a single chip that's small enough to fit in a phone but big enough to contain vital parts such as a central processing unit and a graphics processor. By some measures it was the most powerful chip in the mobile market at the time, and it was a tremendous success for Broadcom.

It was also, Upton realized, the way to restart Raspberry Pi, given that a single-chip computer would be much less costly to produce. He and half a dozen volunteers worked on the new version on evenings and weekends. But the BCM2835 wasn't easy to deal with: it was dauntingly jammed with tiny components, including no fewer than five power supplies.

To keep Raspberry Pi small and cheap, the team wanted to build it on a single circuit board that could be stamped out, no further assembly required. But to enable the phone chip to work with computer peripherals and run full-scale computer software, they would, it appeared, need to build a board with more than eight stacked layers of circuitry, a prohibitively complex and expensive proposition. Working furiously to simplify the circuitry, the team eventually managed to shave the board design down to six layers.

The first prototypes were ready in December 2011, but Upton discovered, to his horror, that they didn't work at all. Fighting panic at the thought of all the various subtle flaws that might be buried in all those layers of tangled circuitry, the team discovered that one pin on the chip had been inadvertently disconnected. It was a blessedly easy fix, and within minutes, his invention was popping to life.

The Raspberry Pi is strikingly unlike other computers. About the size of an Altoids box, the computer has no keyboard, monitor, or disk drive—it doesn't even have an internal clock or an operating system. In other words, the machine requires a fair amount of hardware and software tinkering just to get started. It almost dares you to take it on and try to hack together a robot or gaming system.

It can't get by on looks. Lacking a case, the Raspberry Pi offers a dense, bristling cluster of tiny electronics to the owner's view, with five ports: HDMI, to hook the computer up to a television; USB, to hook it to multiple devices; Ethernet, for data; and analog TV and analog stereo. But having to face the guts of the device is a good thing, according to Upton. "Kids can see what they ordinarily can't see, unless they smash a phone," he says.

The really surprising feature of the Raspberry Pi is the $25 price: about a tenth the cost of the lowest-priced computers available in stores (if you ignore tablets, which no one can hack anyway).

It was intended for kids, but hackers of all ages wanted it, and so did budding computer scientists in poor countries. Almost the instant the Raspberry Pi went on sale, orders crashed the websites of its two vendors, RS Components and Premier Farnell. The companies reported that they were taking in orders fast enough to tear through the entire initial stock of 10,000 computers in minutes.

Thrilled with the reception, Upton is making more of the devices through a nonprofit Raspberry Pi Foundation he put together—his mercenary tendencies having abated over the years. In fact, he says, he intends to sell two million Raspberry Pis a year in order to reach a critical mass that will support an active community of owners to share tips and applications. He also hopes that the existence of this community will prompt schools to adopt the Raspberry Pi for courses.

Even more important, Upton hopes, is that kids start to take them apart. "That would be real success," he says.

—Charles C. Mann

HOSSEIN RAHNAMA

Mobile apps that tell you what you need to know before you have to ask

AGE: 32
AFFILIATION: Flybits

PROBLEM: We're forced to interact with smartphones in much the same way that we do with desktop computers—by selecting applications, typing in information, choosing from menus, hunting down snippets on websites, and clicking links. That's okay at a desk, but it can be a huge inconvenience when you're dealing with a tiny screen on the go.

SOLUTION: Hossein Rahnama, research and innovation director of the Digital Media Zone at Toronto's Ryerson University, decided that smartphones ought to offer us useful information where and when we need it.

Through his startup, Flybits, Rahnama is laying the technical groundwork for a wave of mobile software that can identify and respond to contextual cues like location and time of day—and integrate them with information such as a user's travel itinerary. It can then guess at what information would be most relevant to display, such as directions to a car-rental counter when you get off the plane after arriving at an airport.

Others have been working on so-called context-aware computing, but Rahnama's software platform is already being used as the basis for inexpensive, commercially practical applications that also protect privacy. Several Canadian airports and the transit systems in Toronto and Paris have used the Flybits platform to create apps that automatically serve up personalized, location-keyed guidance to travelers, and a small U.K. telecommunications company is using it to develop apps that can route calls to the appropriate number to help you avoid roaming fees (for example, it knows to send your mom's call to your hotel landline rather than your cell if it detects that you're overseas).

Flybits can also make it easier to find the people most relevant to your location and interests. The company is rolling out a service called Flybits Lite that prompts users to form spontaneous social networks limited to a certain space, such as the office or a concert. So eventually, after you've navigated the Metro to the Louvre, perhaps you can find out who else is there to admire the *Mona Lisa*.

—Jessica Leber

Saikat Guha

Letting advertisers send targeted pitches to your mobile phone without ever seeing your personal information

AGE: 30
AFFILIATION: Microsoft Research India

Saikat Guha is convinced that privacy and profit don't have to conflict online. The Microsoft Research India computer scientist has developed a software platform that allows advertisers to precisely target potential customers without exposing the customers' personal information.

The trick involves flipping the basic model of targeted advertising. Companies now track your browsing and purchasing behavior and then sell your data to advertisers. But instead of acquiring data from your phone or PC so that companies can send the right ads to websites you visit, Guha's system calls for companies to send potential ads to you; then software on your device figures out which of them are targeted effectively. Thus, if you search for video games, the software will fetch entertainment-related ads. If your computer or phone recognizes that, say, you often buy DVDs, the device will pick out a DVD ad to show you. Guha's ad-selecting software could be built into browsers, or into websites such as Facebook. And he estimates that the ads wouldn't take up significant amounts of memory on your machine.

Since companies wouldn't be able to see or store your data or toss it around the Web, risking accidental leakage, even data normally too private to share with advertisers could be brought to bear in picking from among them.

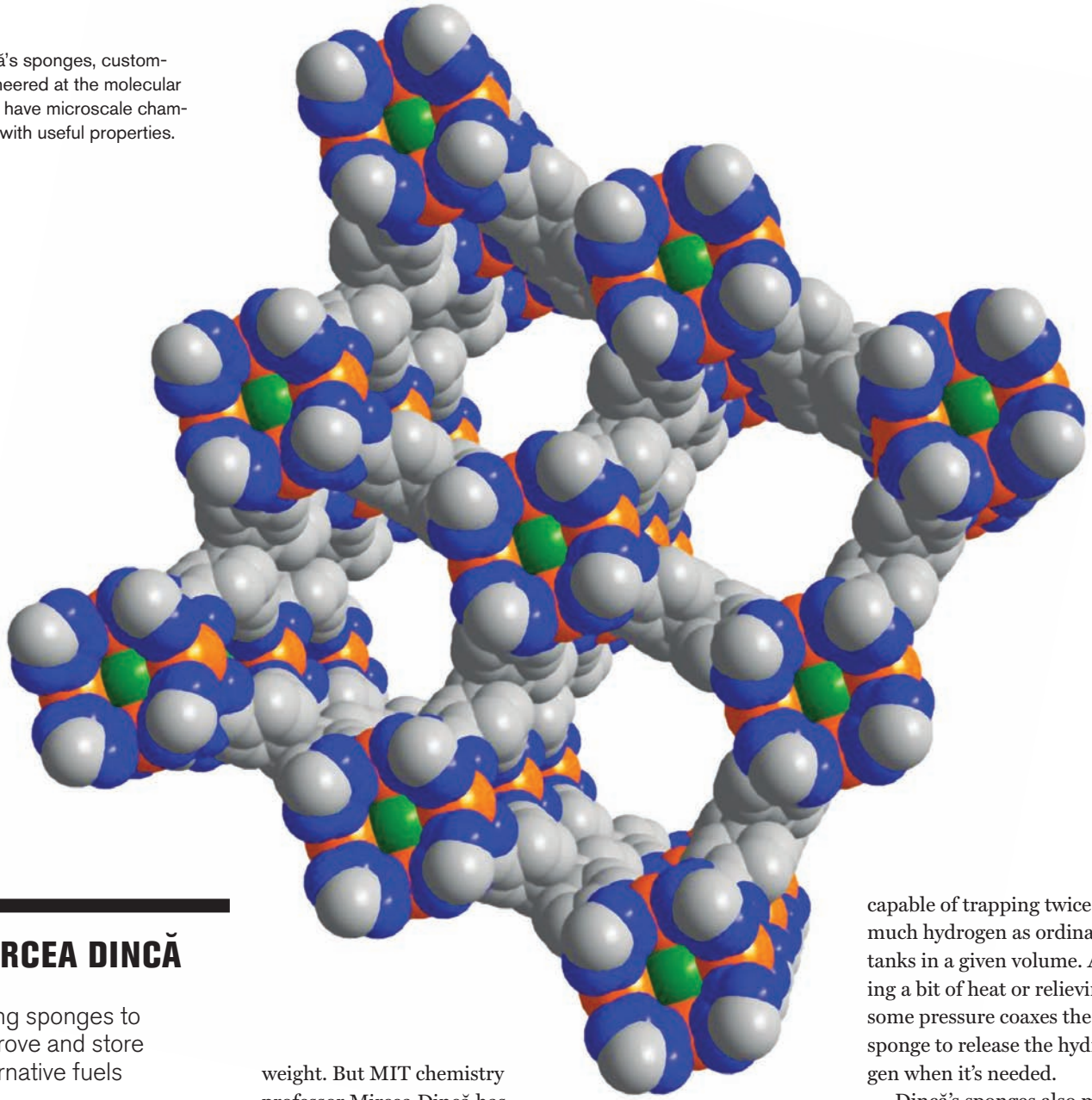
Today, for instance, Google can't determine your birth date unless you offer it up. But Guha's software might come across it on your PC and use it to enhance the targeting of Google's ad network, without ever revealing the date to Google. It's a privacy protection scheme that, unlike almost all others, indirectly gives businesses an even richer set of data to work with.

Guha has also addressed the privacy threat from smartphone apps that package and sell sensitive information such as a user's name and location. "Today someone could construct a full history of where you are at any given time of the day," he says. His idea is a platform that cryptographically splits information such as a person's name, the name of the store the person is visiting, and the amount of time spent at the previous store into disconnected fragments before sending it to the cloud. Software on the phone or tablet could then use all or most of those fragments to target advertisements, but no party involved could connect them to create a privacy-violating portrait of the user.

There will always be those who will try to get around privacy protection schemes to scope out more about you than you care to share. Guha is on top of that problem, too. He's working on algorithms that detect when websites and apps are surreptitiously using your personal data, so you can block them. *—Prachi Patel*

Guha found a way to protect privacy while delivering customized ads to your phone.

Photograph by Sami Siva



Dincă's sponges, custom-engineered at the molecular level, have microscale chambers with useful properties.

MIRCEA DINCĂ

Using sponges to improve and store alternative fuels

AGE: 32
AFFILIATION: MIT

Clean energy tends to come with drawbacks. Hydrogen has such low density that it's hard to compress a useful amount of it into a container small enough to be practical; natural gas is more costly to transport and transfer than liquid fuels; batteries hold relatively little energy for their size and weight. But MIT chemistry professor Mircea Dincă has come up with a promising way to solve all these problems: sponges.

Dincă uses organic and metallic materials to form his sponges, which are so thoroughly riddled with microscopic chambers that in some cases, the surface area of just a gram would cover a football field if laid out flat. By mixing and matching these building blocks, he is able to control the size of the tiny chambers. Different configurations have different chemical and electrical properties.

Getting enough hydrogen on board a hydrogen-powered car requires either ultrahigh-compression tanks or cryogenic fuel tanks, but neither of these methods stores enough hydrogen to meet the U.S. Department of Energy's target: a vehicle that can travel 300 miles without refueling. Dincă came up with a sponge capable of trapping twice as much hydrogen as ordinary tanks in a given volume. Adding a bit of heat or relieving some pressure coaxes the sponge to release the hydrogen when it's needed.

Dincă's sponges also make great sites for catalytic reactions, because the whole inner surface can be coated with a catalyst; the reaction can be controlled by altering the size of the sponge's pores. He is developing variants of the sponges that could transform methane into a liquid fuel by efficiently catalyzing reactions that strip oxygen from air. He is also working on turning these sponges into materials for batteries and for organic photovoltaics.

—Kevin Bullis

COURTESY OF MIRCEA DINCĂ

CHRISTINA FAN

Prenatal testing for genetic conditions from a sample of the mother's blood

AGE: 29
AFFILIATION: ImmuMetrix

There's never been a great way to safely and accurately test what's going on in the womb. The mother's bloodstream contains some fetal cells, but not many of them, so a maternal blood sample rarely yields enough for a useful analysis. Now Christina Fan has come up with an approach to measuring the chromosomes and genes in the fetus without having to isolate the fetal cells, enabling her to develop tests for Down syndrome and a range of inherited and other conditions.

While still a graduate student in bioengineering at Stanford, Fan developed a DNA sequencing technique as well as an algorithm for estimating how many of certain chromosomes—such as chromosome 21, the one implicated in Down syndrome—should be present in a sample of the mother's blood if the fetus is contributing the expected number. Any excess in the sample means the fetus has more than the normal number of the chromosome, indicating that the child is likely to have Down syndrome. There are other blood tests for this condition, which affects cognitive and physical development, but these tests are much less accurate. There are also more accurate tests performed on fluid drawn from the amniotic sac, but collecting this fluid carries a small chance of triggering a miscarriage.

Fan realized that to expand her work to other inherited conditions, she had to go beyond simply counting chromosomes and look at the genes associated with those conditions. She was able to adapt her chromosome technique for these other condition by calculating, from an analysis of both the mother's and father's cells, how much of a certain type of gene ought to turn up in a sample of the mother's blood. If the sample contains higher levels than expected, the excess is coming from the fetus. "We used this method to build the entire inherited fetal genome from maternal blood," she explains.

Some of the conditions that are detectable this way can be prevented from causing problems if they're treated promptly at birth. The metabolic disorder phenylketonuria, for example, can be managed through diet if that begins when the patient is a newborn. *—Karen Weintraub*

In her lab, Fan is developing better ways to spot genetic disorders in fetuses.

Photograph by Jake Stengel

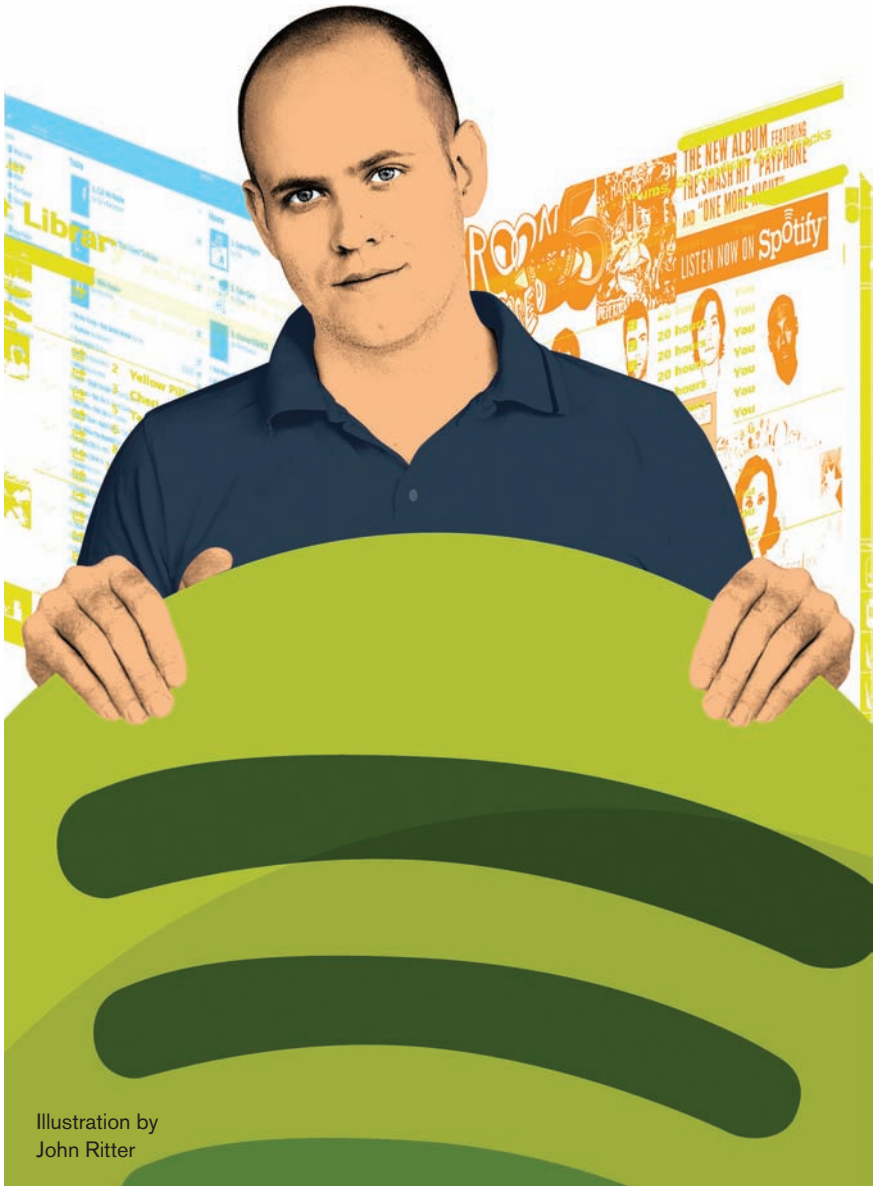


Illustration by John Ritter

Daniel Ek

Making online music a paying business, without forcing people to pony up for one song at a time

AGE: 29
AFFILIATION: Spotify

In 1999 Daniel Ek was a 16-year-old Swedish programmer, getting rich building websites, when he started asking what he himself now says was a dumb question: How do you get people to pay for music that can, if illegally, be downloaded free—and without charging them for each song, the way Apple's iTunes service does now?

Ek's eventual solution: Spotify, a jukebox in the cloud that provides legal, on-demand access to millions of songs. Supported by paying subscribers, as well as by radio-style ads played only to nonsubscribers, the service debuted in the United States last year after operating for three years in Europe; it now has more than 15 million users, four million of whom pay. With an estimated value of $4 billion, Spotify is one of the hottest Internet companies in the world.

Spotify isn't the only service to let listeners stream music on demand. But it distinguishes itself from Internet radio services like Pandora and Slacker through the vastness of its music libraries and its deep integration into social media. Spotify lets users seamlessly share playlists and swap music on social networks like Facebook and Twitter. And Spotify makes it easy for others to build apps that work with its platform in order to give users yet more ways to discover and share music. "The trick was to think through the social aspect of the service from the very beginning," says Ek. "We didn't want it to be an afterthought."

Spotify's users can access some 16 million songs—about 15 times more than Pandora makes available. The service offers all those terabytes of music without revealing any of the licensing complexities involved in the process. Ironing out the needed deals with record companies while refining the service ate up two years of Ek's time before he launched in Europe in 2008. And it took a team of software engineers—the company now has 250 of them—to make the service easy to use in spite of all the programming code that works in the background to prevent music from being illegally copied and distributed. "The best thing about Spotify is that it works at all," says Ek. "If you're in Spain and you want to share your music with someone in the U.K., you don't want to see how we take care of paying licensing fees in both places."

Now Ek is trying to find ways to make it as easy to find and play music as it is to find and play videos on YouTube. This year the company introduced a radio service for computers and mobile devices, launched its first iPad app, and made it possible to embed a Spotify play button into any website. The Huffington Post, the blogging site Tumblr, and *Rolling Stone*'s website are among the many that now offer music that way.

For a man capable of turning his teenage vision into a mushrooming empire, Ek claims a surprisingly simple strategy for continued growth. "I just keeping asking dumb questions," he says. *—Nicole Dyer*

ANDREAS VELTEN

Spotting tiny problems with help from an ultrafast camera

AGE: 32
AFFILIATION: University of Wisconsin, Madison

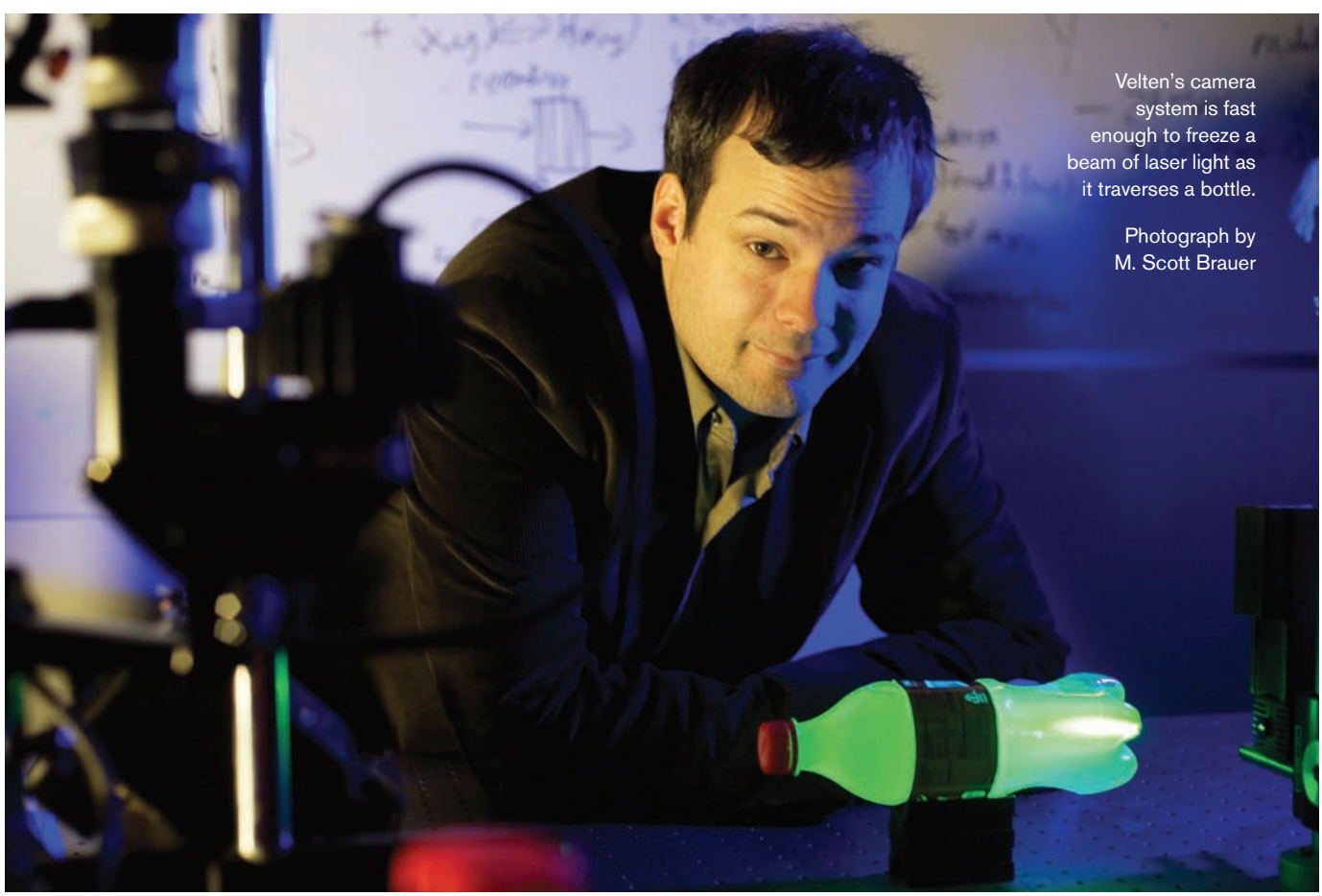
A CAMERA TO FREEZE LIGHT OR SEE AROUND CORNERS

Nothing moves too fast for Andreas Velten's camera—not even light. Last year Velten, who built the camera while a postdoc at the MIT Media Lab's Camera Culture Group, made a video of laser light zipping through a plastic soda bottle. Capturing the equivalent of 600 billion frames per second, the slow-mo footage showed a ghostly light moving from one end of the bottle to the other. Equally remarkable, the camera can harness light reflected off surfaces to see around corners. Because the camera is so fast, it can detect how long it takes the different light rays to reach it, and an image can be reconstructed from that information.

It's not just amazing gimmickry. Velten's technology could lead to ultrafast medical imagers and scanners that use light instead of sound to detect tiny imperfections, whether in cancerous tissue or in airplane wings. It also suggests an approach to taking high-quality photos of scenes lit only by the tiny flash on a cell phone.

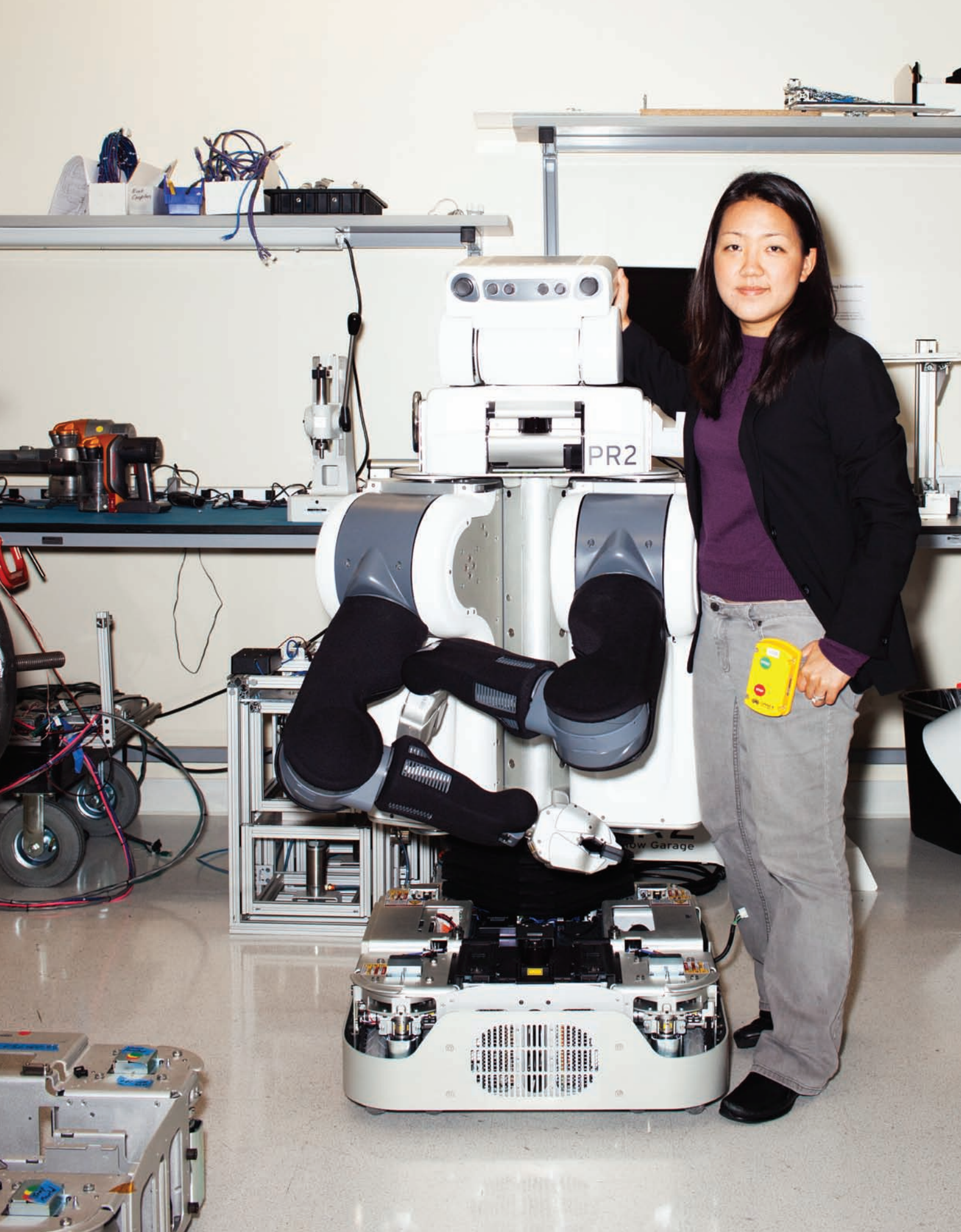
Velten's table-mounted camera uses 672 carefully positioned and timed optical sensors, each capable of capturing a trillionth of a second's worth of reflected laser light. The technical advance was figuring out how to modify a streak camera, a common piece of equipment in chemistry labs that measures the optical properties of laser light. That type of camera can capture only one horizontal line, or "streak," of light at a time. Velten, combining his expertise in optics and computer science, developed custom software to repeat the scan over and over and combine the resulting data.

Now at the Morgridge Institute at the University of Wisconsin, Velten is applying his ultrafast imaging techniques to help develop new types of microscopy and biomedical imaging for clinical applications. One of the tools he envisions, for example, is a less invasive endoscope that could travel shorter distances to see deeper inside the body. *—Conor Myhrvold*



Velten's camera system is fast enough to freeze a beam of laser light as it traverses a bottle.

Photograph by M. Scott Brauer


PR2

Takayama has helped make a robot called PR2 less intimidating for the elderly and others who might need it around the home.

Photograph by Jake Stangel

AGE: 31 **AFFILIATION:** Willow Garage

LEILA TAKAYAMA

Applying the tools of anthropology to make robots easier to live and work with

People often find robots baffling and even frightening. Leila Takayama, a social scientist, has found ways to smooth out their rough edges. Through numerous studies and experiments that look at how people react to every aspect of robots, from their height to their posture, Takayama has come up with key insights into how robots should look and act to gain acceptance and become more useful to people.

Takayama has had an especially big influence on the design of an advanced robot from Willow Garage, the startup she works for in Menlo Park, California. Called PR2 (see "Robots That Learn from People," September/October 2011), it's an early prototype of a new generation of robots that promise to be indispensable to the elderly, people with physical challenges, or anyone who simply needs a little help around the home or office.

PR2 can fold laundry and fetch drinks, among other impressive tasks. But Takayama suspected that the nest of a half-dozen cameras originally perched on PR2's head would alienate users. To find out, she turned to crowdsourcing, showing images of the robot head to an online audience recruited for the purpose. The results verified her concerns, and she successfully lobbied to jettison all but a few of the cameras, some of which were redundant.

More recently, Takayama has devoted effort to improving a robot called Project Texai, which is operated directly by humans rather than running autonomously. She ran an extensive field study to find out how Project Texai fit into the office environment of several different companies, coming by each office every two weeks to collect feedback and observe interactions between on-site staff and robots operated by remote colleagues. That study led to a surprising insight: "When you control a telepresence robot, there comes a point for a lot of people when they feel as if the robot is their body," she explains. "They don't want people to stand too close or touch the buttons on the screen."

She also discovered that people in the offices ended up being less comfortable with Project Texai if they were allowed to dress it up. Personalizing the robot led people to feel more possessive about it and less accepting of the fact that someone else was controlling it. Project Texai should be personalized, Takayama concluded, but only by the "pilot," and not by those who are around the machine. She also found that robot size can have a big impact on acceptance and is conducting a study to nail down the optimal height for Project Texai. Another key question: is it better to have the robot at eye level with a person who is sitting or standing?

Takayama is now conducting home interviews with the elderly and disabled to figure out which sorts of tasks would be most helpful to them. She predicts that someday soon, older people will employ personal robots to help them communicate with family and friends.

—Jessica Leber

BURCIN BECERIK-GERBER

Using cell phones to negotiate energy-efficient settings in office buildings

AGE: 35
AFFILIATION: University of Southern California

Office towers and commercial buildings account for nearly one-fifth of all energy consumed in the United States. Burcin Becerik-Gerber has found a cheap way to cut a building's energy use by a third.

Today's smart buildings can be programmed to default to energy-thrifty measures, such as turning down the heat or air-conditioning and turning off unnecessary lights—but occupants often just crank everything back up, or even work against the system by plugging in space heaters or opening windows. An assistant professor of civil and environmental engineering at the University of Southern California, Becerik-Gerber has come up with a way to save energy by essentially getting buildings to "negotiate" with their occupants, factoring in the perceptions and desires of each.

The system uses occupants' smartphones to open up a line of communication. Becerik-Gerber worked with colleagues in social psychology and computer science to design an app that asks people how satisfied they are with the work environment's current temperature, lighting, air quality, and even noise level. System software then fashions each user's consumption patterns and preferences into a virtual "agent" that resides in his or her smartphone. "The agent works for you and tries to look after you," she explains.

The system then works with all the building's agents to find the most energy-efficient way of adjusting the settings so as to make the greatest number of people happy. To improve the results, it asks those users demanding more energy-intensive conditions if they'd be willing to compromise a bit, and it tells them what the resulting energy savings would be. "If people understand the consequences, they're more tolerant," says Becerik-Gerber. The optimized settings are then put in place and monitored automatically.

Finding an optimal solution for as few as five occupants is difficult. Finding a way to coördinate the preferences of hundreds was massively challenging. The problem is especially acute in today's popular open-plan offices: people with very different preferences often share space, typically guaranteeing that most of them will be unhappy with the environmental settings. But Becerik-Gerber's simulations indicate that her algorithms could satisfy some 70 percent of occupants—while reducing overall energy consumption by more than 30 percent. *—Peter Fairley*

Illustration by John Ritter

HER APP "WORKS FOR YOU AND TRIES TO LOOK AFTER YOU"

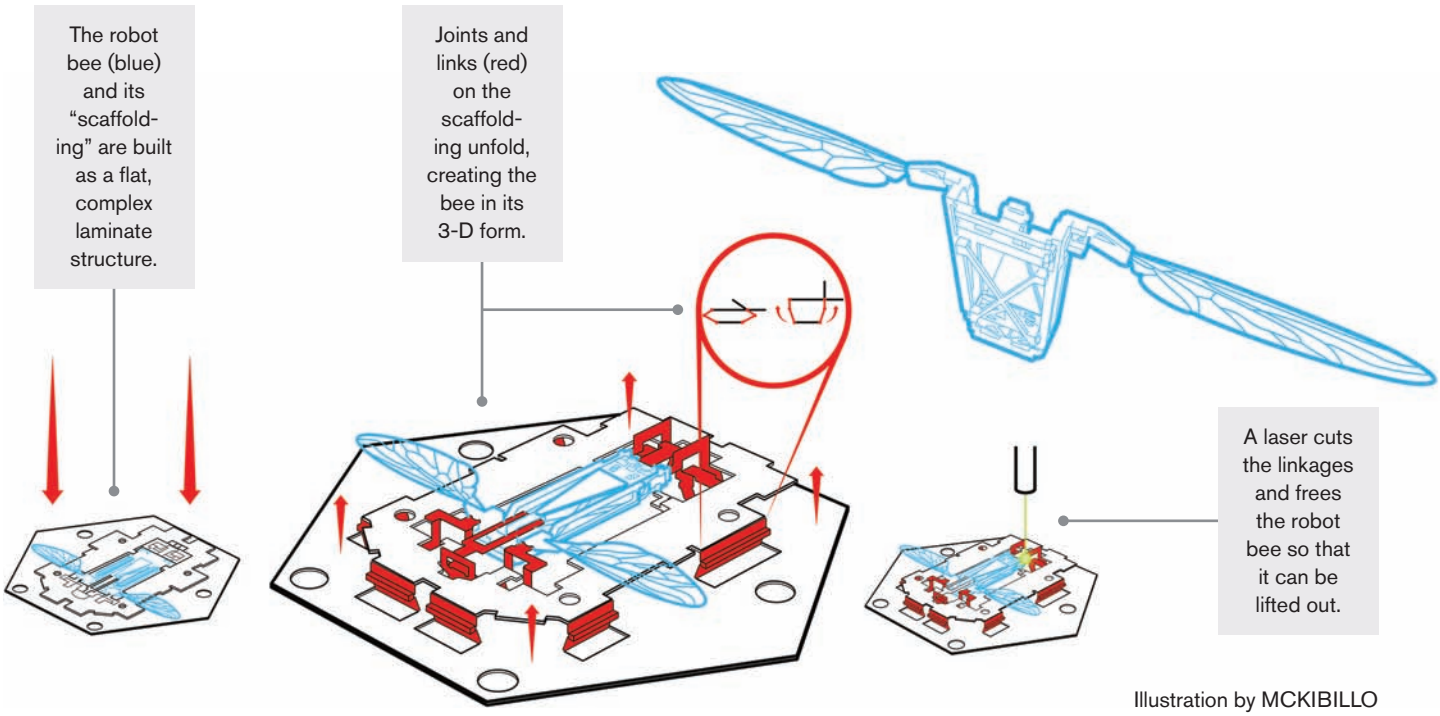


Illustration by MCKIBILLO

PRATHEEV SREETHARAN

Mass-producible tiny machines snap into place like objects in a pop-up book

AGE: 28
AFFILIATION: Vibrant Research

Combining tools used to manufacture printed circuit boards with the spirit of origami, Pratheev Sreetharan has found a way to build tiny machines and complex objects that were previously impossible to fabricate without assembling them manually. Some of the results: a robotic bee created in a day, a tiny, precise icosahedron, and a small chain of interlocking carbon-fiber links. The small, intricate items demonstrate a fundamentally new fabrication approach that Sreetharan believes can be broadly applicable in making a range of new medical devices, robots, and components of analytical instruments.

If Sreetharan is successful, he could open up the manufacturing no-man's-land between the micrometer-scale features of silicon chips and the centimeter-plus scale of everyday items. It's a size range that's of critical importance in biology and medicine. But today there's simply no practical way to mass-produce three-dimensional objects and complex machines on this in-between scale.

Sreetharan's prize creation is the robot bee, fabricated through a series of steps inspired by pop-up books. As a graduate student in the lab of Harvard microrobotics pioneer Robert Wood (a member of the 2008 TR35), Sreetharan was familiar with the task of laboriously gluing the miniature robots together under a microscope, and his fabrication approach was born of his determination to find a better way.

He began by adapting standard lamination and micromachining techniques from circuit board manufacturing to carve the needed parts into a flat substrate. But the real trick came in adding features that allowed the parts to pop up and lock into place in one step, creating the bee.

Sreetharan, who spent a recent summer in the Indian region of Tamil Nadu teaching Sri Lankan refugees about renewable energy and designing a solar-powered computer charger, recently got his PhD from Harvard and founded a startup called Vibrant Research in Cambridge, Massachusetts, to adapt his fabrication methods to advanced manufacturing.

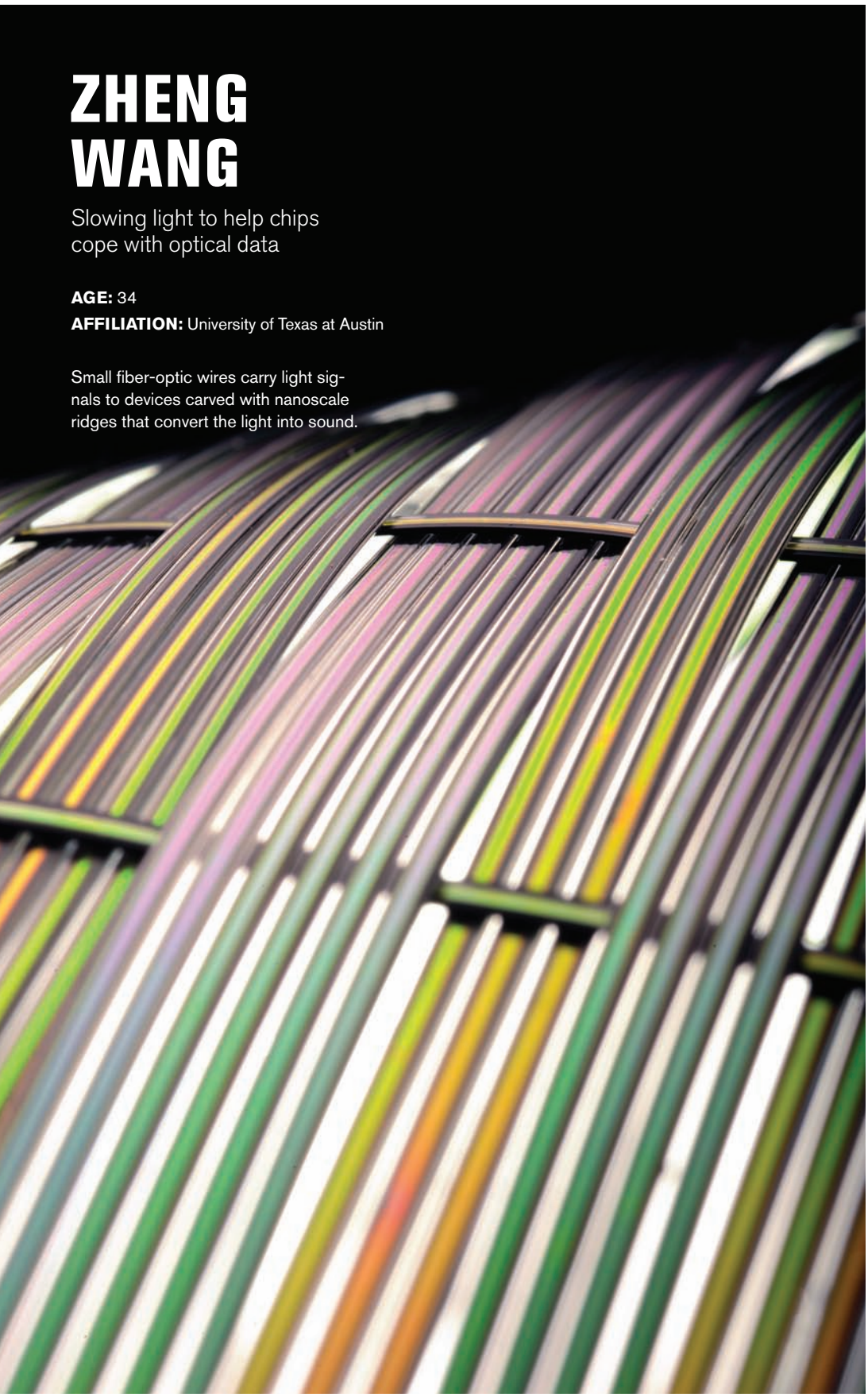
He is still deciding which specific products the company will focus on, but he says he is able to routinely make objects that have never before existed. And he hopes the novel production methods will create new opportunities in manufacturing. That would be a pretty good way to build on the buzz from his robot bee.

—David Rotman

ZHENG WANG

Slowing light to help chips cope with optical data

AGE: 34
AFFILIATION: University of Texas at Austin



Small fiber-optic wires carry light signals to devices carved with nanoscale ridges that convert the light into sound.

GREG HREN

Light beams are so fast that using them to replace electrons would make for vastly more powerful and energy-efficient chips, even paving the way for quantum computing. At times, though, light is too fast. That's why Zheng Wang decided to slow it down. "The speed is very good for optical communications but very bad for processing signals on-chip," he says.

To slow light, Wang, an assistant professor of electrical and computer engineering at the University of Texas at Austin, created nanometer-size ridges on a chip. The ridges are so slender and flexible that they can be deformed by electric fields. When light is delivered by optic wire to the ridges at the edge of the chip, they convert the light waves to high-frequency sound waves, which travel at about a 100,00th the speed of light. The same trick works in reverse after the sound waves have traversed the chip, with the ridges converting the sound back into light to continue its higher-speed journey via optic wire.

Other researchers had accomplished similar feats with light—but only by enlisting a high-powered pulse laser that generates acoustic pulses, a much less efficient and larger-scale process that can't be handled on a chip.

Sound waves are much easier to read and route within the tiny confines of a chip. And they offer the huge advantage of not generating the heat that electronics do. That makes Wang's approach promising for applications in information processing, as well as in nanoscale microscopy. *—Neil Savage*

Houston created the first version of the file storage service Dropbox on a bus ride.

Photograph by Winni Wintermeyer

Drew Houston

Hiding all the complexities of remote file storage behind a small blue box

AGE: 29
AFFILIATION: Dropbox

One day in 2009, Drew Houston and his business partner, Arash Ferdowsi, pulled their Zipcar into Apple headquarters in Cupertino, California. "We went to the front desk," Houston recalls. "And what do you say at that point? 'We're here to see Steve.'"

Steve Jobs had invited them largely because he wanted to explore acquiring Houston's fast-growing company, Dropbox. Founded in 2007, Dropbox conferred iPhone-like ease and reliability on cloud-based file storage—something Apple hadn't yet begun offering itself. People using any browser or operating system, on any kind of device, could drag any kind of file to Dropbox's icon of an open blue box. The files were stored on Dropbox's servers and synched each time you saved a file, so that it would be available on any device running Dropbox.

Houston and his team hammered out thousands of issues to create an easy system free of the typical annoyances. Dropbox knows that while Linux file names are case-sensitive, Windows file names aren't, so a Windows file called "ABC.doc" will overwrite one called "abc.doc." It can keep antivirus software from interfering with its file-synching system. It integrates smoothly with different user interfaces: on a Mac, for example, the Finder displays a check mark in the Dropbox icon when files are in sync.

Its ability to shield users from myriad mind-numbing details and housekeeping chores—"the acrobatics to support all these different situations," as Houston puts it—is what made Dropbox a hit. "It sounds like what we do is simple," says Houston, who wrote the original code on a bus ride from Boston to New York and is now Dropbox's CEO. "But sanding down the thousand rough edges to make something work 100 percent of the time is really, really hard. Even something simple, like synching a file, is actually really complicated to do in a bulletproof way a billion times."

That's how many times people are updating files with Dropbox every two days. And as consumers slide more stuff into their Dropbox folders, more blow past their free two-gigabyte limit and start paying $10 a month for additional storage. Dropbox says it now has more than 50 million users, with 4 percent paying.

The other big technical challenge was how to make Dropbox work fast on any device. Users often store thousands of files, and tracking and synching every one of them could easily eat up memory and processor time. The first version of the service hogged two full gigabytes of memory, but Dropbox eventually whittled that down to a mere 100 megabytes. And to keep Dropbox from dropping the ball when operating systems are revised or upgraded on users' PCs, the company created custom analysis tools that rapidly detect and resolve any software conflicts.

Houston's team is now working on advanced capabilities for synching and sharing photos, and gearing up for the demands that will be imposed on the software by continued rapid growth. "We're designing a system that can connect billions of devices," he says. The company has tripled its staff in the past year, to 150, and taken over a large office space in San Francisco.

Back at that meeting at Apple in 2009, Houston told Jobs he wasn't interested in selling, after which Apple went on to bring out its competing iCloud service. But it's hard to argue that Houston was being shortsighted, given that private investors recently valued Dropbox at $4 billion. *—David Talbot*

Power plants like the one behind Chen (left) will be made more efficient by his software.

Photograph by Jeremy Wasserman

Qixin Chen

Improving demand forecasting for electric power to save fuel and reduce emissions

AGE: 30
AFFILIATION: Tsinghua University

PROBLEM: Many power plants connected to the grid operate well below their full capacity, wasting fuel. If we have no means to store large amounts of electricity or reliably predict power demand, however, maintaining idle capacity is the only way to respond quickly to surges in demand. The problem is particularly challenging in China, a huge consumer of electricity. Its push to add thousands of wind turbines, with their variable, difficult-to-predict output, will make it even harder to efficiently balance supply and demand.

SOLUTION: Software from electrical engineer Qixin Chen of Tsinghua University in China accurately forecasts power demand and helps utilities coördinate power plants. His software is already in use in nearly 200 cities and 10 provinces in China. One province, he says, reported saving $30 million and 240,000 tons of coal in a single year.

Chen found two ways to improve on existing demand-forecasting software. First, he designed the system to better choose the right forecasting approach for particular areas; differences in demand and weather patterns mean that some techniques are much better suited to some locations than others. Then he enabled his system to analyze its own previous prediction errors and adjust its formulas so as to minimize the errors the next time similar conditions

occur. The result is demand forecasts that are accurate as much as a month ahead. Other forecasting systems, in contrast, aren't accurate beyond a day or two, if that.

The results are helping utilities dole out electricity more efficiently. Now Chen is working to adapt his forecasting software to predict the power output of wind turbines. His system would take into account wind data gathered for miles around the turbines, providing a sharper picture of which wind shifts are likely to affect them in the coming hours. That means utilities can know when to expect more power from the turbines so they can cut back on conventional power generation. *—Kevin Bullis*

JUAN SEBASTIÁN OSORIO

Monitors specially designed for premature infants help detect breathing problems

AGE: 25
AFFILIATION: Antioquia School of Engineering and CES University

Illustration by Michael Gillette

Nearly 85 percent of babies born before 34 weeks stop breathing for 20 seconds or more, often because their undeveloped nervous systems fail to signal their lungs. That can be fatal. The babies are typically hooked up to monitors, but sometimes the systems fail to sound the alarm—and Juan Sebastián Osorio discovered why.

Osorio, then a biomedical-engineering student with the Antioquia School of Engineering and CES University in Medellín, Colombia, realized that the sensors used on the infants were poorly adapted to their small size. Electrodes are placed on either side of the infant's chest to watch for stoppages in motion. But the tiny chests move so little that the monitor can mistake heartbeats for breathing motions long after respiration has stopped.

Osorio and colleagues came up with a prototype detector attuned to the rhythms of infant physiology. The monitor combines heart rate recordings, electrical signals from the diaphragm muscle, and blood oxygen measurements for a potentially more precise and reliable way to measure a baby's breathing. Eventually the device could predict the risk of apnea by analyzing the measurements along with information about the baby's weight and gestational age. Osorio says that could help hospitals discharge low-risk babies earlier, saving costs and sparing the babies from extended ICU stays.

Osorio is testing his system and seeking to license it commercially. He's integrating it with a mobile-phone app he developed that helps parents recognize signs of risk for sudden infant death syndrome. Next he plans to couple his detector with a video camera to make it easier for parents to monitor babies at high risk for apnea. If a problem comes up, the system will connect to pediatricians remotely.

—Courtney Humphries

A NEW WAY TO KEEP TABS ON AN INFANT'S BREATH

Turning a Web video phenomenon into a profitable business by making ads optional

AGE: 33 **AFFILIATION:** YouTube

SHISHIR MEHROTRA

In 2008, when Shishir Mehrotra joined YouTube to take charge of advertising, the booming video-sharing service was getting hundreds of millions of views a day. YouTube, which had been acquired by Google in 2006, was also spending as much as $700 million on Internet bandwidth, content licensing, and other costs. With revenue of only $200 million, YouTube was widely viewed as Google's folly.

Mehrotra, an MIT math and computer science alum who had never worked in advertising, thought he had a solution: skippable ads that advertisers would pay for only when people watched them. That would be a radical change from the conventional media model of paying for ad "impressions" regardless of whether the ads are actually viewed, and even from Google's own pay-per-click model. He reckoned his plan would provide an incentive to create better advertising and increase the value for advertisers of those ads people chose to watch. But the risk was huge: people might not watch the ads at all.

Mehrotra's gamble paid off. YouTube will gross $3.6 billion this year, estimates Citi analyst Mark Mahaney. The $2.4 billion that YouTube will keep after sharing ad revenue with video content partners is nearly six times the revenue the streaming video service Hulu raked in last year from ads and subscriptions. And that suggests Mehrotra has helped Google solve a problem many fast-growing Web companies continue to struggle with: how to make money off the huge audience that uses its service free.

In 2008, Mehrotra was working for Microsoft and hankered to have his own startup, but he agreed to talk to a Google executive he knew about working there instead. He decided against it—but that evening he kept thinking about how the exec was frustrated that most ad dollars go to TV, even though nobody watches TV ads. Yet at his Super Bowl party two weeks earlier, Mehrotra recalled, guests kept asking him to replay the ads. Was there a way, he wondered, to make TV ads as captivating as Super Bowl ads, every day?

The answer came to him in a flash. The next day, he had changed his mind about working at Google. After he tried his idea for skippable ads on a television project, the company asked him to bring the idea to YouTube.

YouTube was searching for alternatives to standard "pre-roll" ads, which performed poorly because viewers didn't want to sit through a 30-second ad to watch a two-minute video. In 2010, Mehrotra's alternative came to fruition as YouTube rolled out its TrueView ads. One type lets viewers choose from three ads. Another lets them skip an ad after five seconds; advertisers pay only if their ads are watched in their entirety, or for at least 30 seconds if the ads are longer than that.

Thousands of advertisers piled in. Now some 65 percent of ads inside YouTube videos are skippable. But YouTube has found that only 10 percent of viewers always skip ads, and viewership is 40 percent higher on videos running TrueView than on those with non-skippable ads. As a result, Mehrotra says, video viewed on YouTube brings in more ad revenue per hour than cable TV.

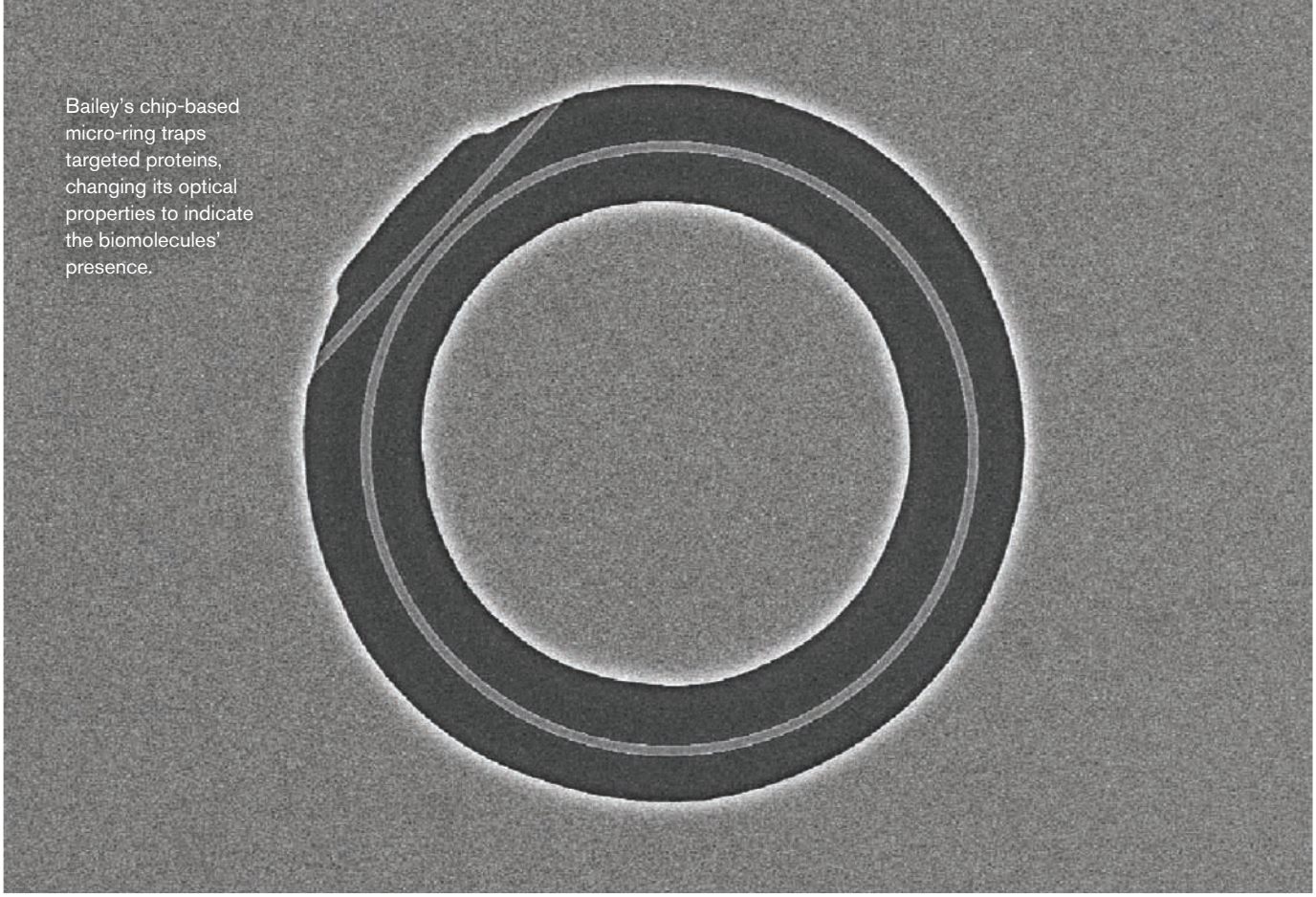
Thanks to Mehrotra's ad model—and to Google's crackdown on piracy of television shows and films—YouTube now attracts top-line content producers such as the nonprofit academic-tutorial producer Khan Academy, Paramount, and the NBA. Revenues paid to YouTube's 30,000-plus video-making partners have doubled in each of the past four years. Thousands of partners get six-figure annual revenues from the ads, and a few take in tens of millions of dollars.

The result is a virtuous cycle. "The more money we bring in, the better content they produce, the more there is for viewers to watch, and so on," Mehrotra says.

Now Mehrotra's goal is to try to grab a big chunk of the $60 billion U.S. television business. But to do that, and fend off TV-content-oriented online rivals such as Hulu, YouTube has to become a bit more like conventional TV. To that end, it organized itself last year into TV-like channels, investing $100 million in cable-quality launches from Ashton Kutcher, Madonna, the *Wall Street Journal*, and dozens of others. More and more TV advertisers are being won over, says David Cohen, chief media officer at the media buying agency Universal McCann. "They're getting marketers to think about YouTube as a viable outlet," he says.

Mehrotra, who last year became YouTube's vice president of product, envisions millions of online channels disrupting TV, just as cable's 400 channels disrupted the four broadcast networks. "We want to be the host of that next generation of channels," he says. *—Robert D. Hof*

Illustration by
John Ritter



Bailey's chip-based micro-ring traps targeted proteins, changing its optical properties to indicate the biomolecules' presence.

RYAN BAILEY

Shining a light on faster, cheaper, more accurate medical tests

AGE: 34
AFFILIATION: University of Illinois at Urbana-Champaign

Tests to detect rheumatoid arthritis, lupus, and other autoimmune diseases can cost hundreds of dollars and take days, and they aren't always accurate. To address those shortcomings, Ryan Bailey, a chemist at the University of Illinois, developed a silicon testing chip that fuses optical sensor technology with semiconductor fabrication methods.

Bailey's chip is faster and more sensitive than many other optical tests, which typically look for color changes or fluorescence in response to telltale proteins. And it also outperforms many tests that detect changes in the electric charge of proteins and DNA.

The device can detect almost vanishingly small concentrations of proteins in 10 minutes or less—which means test results can be put to clinical use during an office visit. For most assays, samples can be placed on the chip without any of the preparation required in current systems, making the test easy to run with little training. And at about one dollar per test, it costs a fraction as much as most others.

Each silicon chip has an array of 30-micrometer-wide rings. Each ring can be coated with a molecular trap for a different protein, gene, or biomarker. If light of a certain wavelength shines onto the empty rings, it will resonate and appear brighter to an optical scanner positioned over the chip. When a sample is washed over the chip, any sought-after molecules in the sample will be trapped on the rings—and the change causes the light to resonate at a different wavelength. The wavelength also varies with the amount of trapped material.

In 2007 Bailey helped launch a company called Genalyte; it recently introduced its first diagnostic assay for connective-tissue autoimmune diseases, with a focus on lupus.

The company is also working on applications of the technology in diagnostics for cancer and for cardiovascular and neurodegenerative disease. It is currently producing chips with 128 rings, but Bailey expects the number to go up. His group is also working to simultaneously detect two different kinds of biological molecules on a single chip, such as a protein and an RNA molecule.

—Susan Young

QUICK BLOOD TESTS THAT DON'T REQUIRE ANY SAMPLE PREP

COURTESY OF RYAN BAILEY

Abraham Flaxman

Combining different types of data in new ways in order to track and slow the spread of disease in developing countries

AGE: 34
AFFILIATION: University of Washington

People studying public-health issues must cope with surprisingly shoddy data. Plenty of numbers are available, but epidemiologists and policy makers often don't trust them, because they are frequently incomplete, inconsistent, and inaccurate. "When I came to global health, I was shocked by how little we knew," says mathematician Abraham Flaxman, an assistant professor of global health at the Institute for Health Metrics and Evaluation at the University of Washington.

In response, Flaxman has developed improved models and algorithms that can automatically fill in the gaps in flawed health data. His breakthrough approach, which is now widely used, came from a realization that improving the quality of a large data set requires not just analyzing it on its own but also cross-analyzing it against other relevant data sets that have at least some variables in common.

Flaxman started off as a postdoctoral fellow with Microsoft Research's Theory Group, where he studied complex networks, but he soon yearned to apply his mathematical and modeling skills to big health problems. When he made the jump to academia, he immediately discovered that public health was beset by serious data problems, and he began trying to address those problems.

Flaxman is using his methodology to track the spread and treatment of a wide range of diseases. His latest model, called DisModIII, starts with all the available data on the incidence and mortality of a specific disease. It then integrates and cross-analyzes the data to produce consistent estimates of the way the disease progresses through a population as a function of age, time, gender, and geography.

About 800 researchers use DisModIII to track more than 140 diseases, including hepatitis B and cholera. Researchers and policy makers had long dealt with data that had to be taken on faith and data analysis tools that were unique to each disease. Applying Flaxman's one tool to different data sets covering many different diseases provides credible, apples-to-apples comparisons of their relative impact. That helps policy makers direct health funds to the interventions likely to save the most lives.

Flaxman continues to come across new areas in which his modeling approaches can play a pivotal role. One of them is determining causes of death. Death certificates in developing countries are often incomplete or inaccurate—if they exist at all. The conventional approach is to collect information about symptoms and other matters from relatives and friends of the deceased person, and have a physician review the results to make an educated guess—a labor-intensive technique called a "verbal autopsy."

Flaxman created a computer program that examined available information about a wide range of deceased people whose causes of death were known in order to come up with accurate correlations between observations and causes. Now the software can determine causes of death far more cheaply than physicians can conduct verbal autopsies, getting it right more often as well.

Flaxman wants to do much more to improve health data; he's driven by the knowledge that the policy and public-health decisions informed by his tools are matters of life and death on a large scale. "These are data that really matter," he says.

—Dwight Davis

Chris Harrison

Liberating us from the touch screen by turning skin and objects into input devices

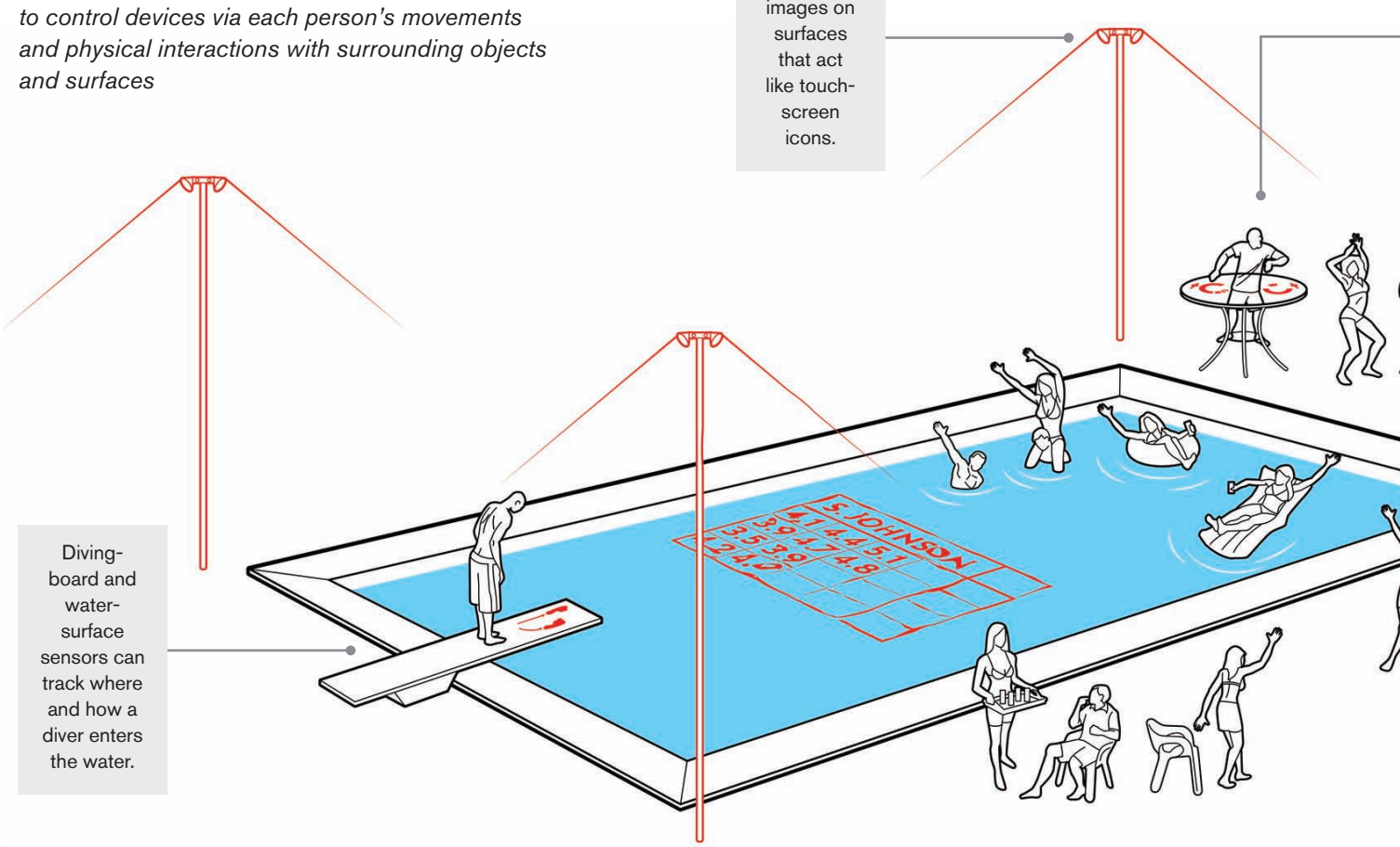
AGE: 28
AFFILIATION: Carnegie Mellon University

Chris Harrison recently helped develop an invention, called Touché, that can turn practically anything into a computer input device—a table, a doorknob, a pool of water, your hand. To do this, he relies on the natural conductivity of some things, or he adds electrodes to objects that aren't conductive. Then he wires up a controller that registers the range of electronic signals the objects generate when they are changed by, say, a particular hand gesture or body posture. A sensor attached to a sofa, for instance, can continuously monitor voltage changes to detect the signatures of particular motions and events and link them to actions. A dog leaping on the couch might trigger a harsh noise to scare it off; a person sitting down might cause the TV to switch on. (Yes, even a couch potato's life can be made easier.)

Harrison, a PhD student in Carnegie Mellon's Human-Computer Interaction Institute, says his mission is to liberate our fingers from having to command our phones and other devices by poking at squished keyboards and teensy screens. "If you think about all the ways we use our hands, being limited to only poking would make the world really hard to use," he says.

He is enlisting technologies ranging from cameras to stethoscopes to miniature projectors. Before Touché, which he developed while at Disney Research, he invented a device called Skinput that turns skin into the equivalent of an interactive touch screen: a tiny body-mounted optical system projects "buttons" onto the wearer's hand and arm and detects any tapping of the buttons so that a device can be controlled. As an intern

A swimming pool area could in theory be wired up with Harrison's electronic-input technology in order to control devices via each person's movements and physical interactions with surrounding objects and surfaces



at Microsoft, he helped create OmniTouch, a roughly similar system that makes it possible to turn any object in the environment into a multitouch screen. And he's made a device called Scratch Input that uses a modified stethoscope and generic microphone to convert the sound of a fingernail dragging over just about any surface into an electrical control signal.

Harrison notes that as computers become better integrated into almost everything we do, we will find it increasingly convenient to be able to interact with them in a variety of ways, without always having to resort to a screen or keyboard. "Eventually we'll develop input technologies so good that we don't need a touch screen," he says. Our tired fingers salute that quest.

—Nicole Dyer

A sensor-equipped tabletop could become a turntable-style music controller.

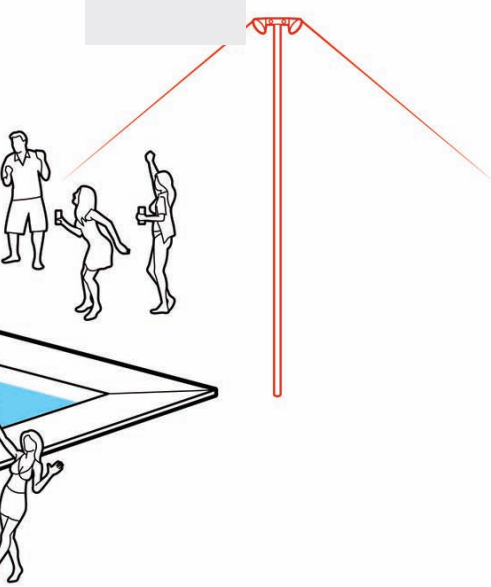


Illustration by MCKIBILLO

Illustration by Michael Gillette

WEIAN ZHAO

Spying on cells in their native habitat to develop better tests and drugs

AGE: 32
AFFILIATION: University of California, Irvine

There are surprisingly few ways to directly observe how cells and proteins work inside living creatures. Weian Zhao devised simple sensors that let scientists do exactly that.

Zhao starts by identifying a short, single-stranded piece of DNA called an aptamer that selectively binds with a protein or other biomolecule researchers are interested in. He attaches a fluorescent dye to the aptamer and then attaches the aptamer-dye combination to the surface of a type of stem cell, found in bone marrow and fat tissue, that homes in on inflamed tissue and tumors.

When the combination of dye, aptamer, and stem cell is injected into a living organism, the stem cell seeks out the targeted biomolecules. For example, if researchers want to look at unhealthy tissue, the aptamer latches onto the biomolecule suspected of being at the root of the problem, and the dye lights up or changes color.

By putting mice that have been injected with these sensors under a special microscope designed to hold a living animal and spot fluorescent dye, Zhao can see where in the organism the dye ends up. He can observe the action down to the level of individual cells, and he can even watch in real time how the biomolecular traffic is altered by the presence of drugs or by other changes in the organism. That's never before been possible.

Zhao's lab is working on a way to rapidly create vast libraries of aptamers that bind to almost any molecule. He foresees scientists using these libraries to build a collection of cellular sensors not only for use in basic research but also to improve the drug discovery process. At present, drug discovery suffers because what happens in cell cultures rarely duplicates what happens in living animals, sometimes misleading researchers and wasting time. Zhao's sensor will allow scientists instead to immediately observe what the drug does inside animals, which can help speed a promising drug toward human trials.

Zhao is also currently working toward getting his stem-cell-based sensors to bind to various cancer markers found in whole blood, in the hope of developing a faster, less expensive, and potentially more accurate diagnostic tool that could even in many cases eliminate the need for a biopsy. He figures that if the work pans out, some of these tests could be on the market within as little as five years. *—Erika Jonietz*

Curving, tiny wires in Lu's patch form a soft and pliable mesh.

Nanshu Lu

Soft, flexible electronics bond to skin and even organs for better health monitoring

AGE: 29
AFFILIATION: University of Texas at Austin

Better integrating electronics with human tissue holds out the promise of monitoring the body more conveniently and accurately than is possible with sensors that are worn or taped on. Nanshu Lu is developing long-lasting "electronic tattoos" that can bond to skin and track and report on the wearer's vital signs or translate small muscle movements into commands for controlling devices. Future versions may play critical roles inside the body in watching for signs of disease or damage. They could even treat problems automatically.

Lu, an assistant professor in the department of aerospace engineering and engineering mechanics at the University of Texas at Austin, has solved a big problem in building electronics for biological tissue: silicon semiconductor circuits are flat, rigid, and brittle, making them a terrible match for the soft, pliable tissue. (See "Making Stretchable Electronics," p. 84.) What is needed is a soft device better able to make intimate contact with skin.

To create a more tissue-friendly chip, Lu enlisted a flexible polymer substrate on which she could deposit small islands of silicon. That technique had been tried by other researchers, but these devices had limited flexibility, since ordinary wires used to connect the silicon tear as the substrate stretches or twists with the tissue's movement. Lu solved the wiring problem by eliminating the islands and replacing them with a serpentine mesh of nanoribbons; this webbing stands up to twisting and pulling without breaking.

The resulting device is a 30-micrometer-thick patch of supersoft, transparent silicone. Lu has built a prototype of the device that carries sensors to measure temperature, strain, and electrical signals. The patch could also be equipped with LEDs to enable visual signaling.

The circuits are printed onto silicone that's supported by a stiffer layer of water-soluble polymer. When the patch is placed on dry skin and then wetted, the polymer layer dissolves; intermolecular attractions between the silicone and skin make the silicone adhere tightly. In tests, the silicone patches have adhered to skin for a week, hanging on even through showers and exercise. And the patches don't irritate skin the way adhesives often do.

Lu and collaborators have already tested the devices in a few applications. For example, they have been attached to people's necks to enable them to control Sokoban games simply by speaking commands; the patches measure the electrical activity of throat muscles during speech, with enough fidelity to distinguish between the spoken words "left," "right," "up," and "down."

Now Lu wants to see the patches used in a wide variety of health-related applications. She hopes to stick the devices on foreheads to directly monitor electrical activity in the brain, to place them on skin during plastic surgery so that strain gauges on the patch can alert surgeons if the procedure is overly stretching skin, to monitor heart rate and muscle activity during exercise, and to track the progress of healing in wounds and burns.

Lu is working on new versions of the devices. For example, she's trying to create stronger physical and electrical connections by integrating arrays of microneedles on the bottom of the silicone patches. That, in turn, could enable the patches to stick to heart muscle so doctors could detect early signs of heart-attack risk, such as reduced blood flow.

Lu also hopes that a version of the patch with two-way communication capabilities might be able to sense heart arrhythmias and instantly respond by delivering small electric shocks to restore an even beat. And she envisions transdermal electronics that could detect the level of a protein in the body associated with a specific disorder and then release drugs to treat it.

—Erika Jonietz

PHOTOGRAPH BY NANSHU LU AND ALEX JEREZ

KEN ENDO

Adding spring to robotic limbs by doing away with some of the motors

AGE: 34
AFFILIATION: Sony Computer Science Laboratories

Robotic limbs are usually packed with multiple powerful motors, making them heavy and bulky. Engineer Ken Endo hit on an idea for lightening and streamlining the limbs: replacing some of the motors with series of springs. His goal isn't to build better robots; rather, he wants to make prosthetic limbs and orthopedic devices that can, as he puts it, "eradicate disability." He hopes to make artificial limbs that function nearly as well as real ones, affording amputees near-effortless motion with no discomfort.

Endo had been focused on building more advanced robots until about seven years ago, when he found himself moved by the determination of a friend who had lost his legs to bone cancer. "He said he wanted to walk by himself," Endo says. "That's when I changed my research focus from robots to biomechanics."

As a PhD student working in the MIT Media Lab's Biomechatronics Group, led by Hugh Herr, Endo created the first computer program that closely simulates human walking, a surprisingly complex motion. Now back in his native Japan as a researcher with Sony, he's enlisting that model to build legs with spring-based ankle and knee joints that he says work much like the real things. "The ankle joint also requires a motor," he notes, "because the human ankle generates a huge amount of mechanical power." But most of the work will be done by the springs, he says, making the legs far more efficient and leaving the wearer less tired and sore. Endo is now perfecting his joints on a walking robot. He hopes to have the bugs smoothed out in mere months, at which point he'll start working to make the device suitable for amputees.

Another big challenge Endo has taken on is making prostheses affordable. More than half of all amputees live in poor countries, where many are victims of land mines. The price tag of $35,000 or more for a high-quality prosthetic leg in the United States is far out of reach for the vast majority of these amputees.

To address that, Endo has been working to design prostheses specifically for people in developing countries and to find ways to distribute them there. He has already achieved one breakthrough: a leg costing about $30 whose knee joint can bend when the leg is lifted off the ground but locks into place when the leg is weighted, leading to a less effortful, more natural-looking gait. *—Courtney Humphries*

Endo's prostheses enlist springs and other mechanisms that allow them to look more natural and feel more comfortable.

Photograph by Jeremy Sutton Hibbert

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A Business Report on

The Future of Work

Destroying jobs and creating prosperity. In this excerpt from our online report, *Technology Review* explores how robots and IT innovations are automating the economy.

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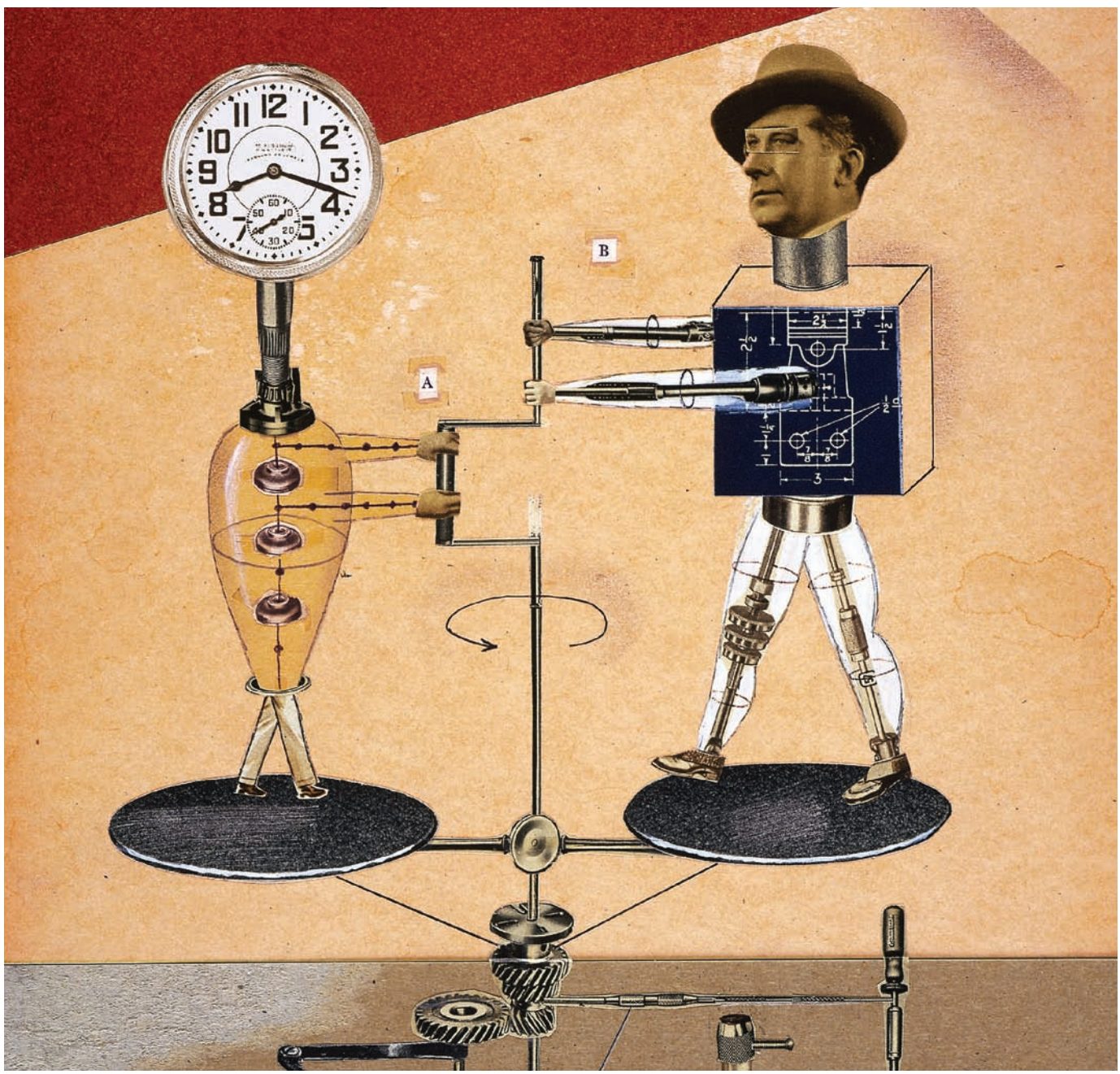


DAVID PLUNKERT

THE BIG QUESTION

Automate or Perish

Successful businesses will be those that optimize the mix of humans, robots, and algorithms.

By ANTONIO REGALADO

In his new book *Automate This*, Christopher Steiner tells the story of stockbroker Thomas Peterffy, the creator of the first automated Wall Street trading system. Using a computer to execute trades, without humans entering them manually on a keyboard, was controversial in 1987—so controversial that Nasdaq pressured him to unplug from its network. Then, with a wink, Peterffy built an automated machine that could tap out the trades on a traditional keyboard—technically obeying Nasdaq rules. Peterffy made $25 million in 1987 and is now a billionaire.

Today, automated trading bots account for nearly three-quarters of U.S. equity trading by volume. Trading houses plow millions into fiber optics and microwave dishes so their algorithms can send trades a millisecond faster than the next guys'. And although the first trading robot was built 25 years ago, most of the change on Wall Street has occurred during just the last few years. When it comes to automation, we may be in the elbow of an exponential curve.

In this business report, we look at this cutting edge of automation. Consider Amazon. The company not only automated book buying but also turned the computer systems it built to do so into a service called Amazon Web Services, making them available for anyone wanting to repeat the feat.

And now Amazon's founder, Jeff Bezos, is placing new bets on automation. In March, Amazon paid $775 million for Kiva Systems, a company that makes robotic dollies that zip across warehouse floors carrying shelves full of goods. Kiva found it was more productive to have the humans who "pick, pack, and stow" items stay in one place and let intelligent shelves come to them. Among other reasons, Amazon said, it bought the robotics firm because the technology offered the chance to reduce labor requirements at its dozens of warehouses.

This is an example of what is going on in the economy more broadly. As the MIT economist David Autor has argued, the job market is being "hollowed out." High-wage, high-skill employment is still being created—and so are many poorly compensated service industry jobs for food preparers, home care aides, and others. It's the jobs in the middle that are disappearing: certain clerical, sales, and administrative jobs and some on factory floors.

Any work that is repetitive or fairly well structured can be fully or partially automated. This may explain why economic output has risen while the number of jobs has fallen.

Now a combination of growing computing power and advances in data crunching means automation is primed to threaten not just tax preparers and travel agents but higher-rung jobs such as those in the medical and legal professions, where software can increasingly do things like analyze images and understand speech more accurately and in more contexts than ever before. Any work that is repetitive or fairly well structured is open to full or partial automation. Being human confers less and less of an advantage these days.

Some economists believe automation may explain why U.S. economic output has grown since 2007 while the number of jobs has fallen. That kind of dislocation is unusual. The U.S. economy has evolved from agriculture to manufacturing to service industries. Each time jobs were destroyed in one sector, they were replaced elsewhere. Data from the Bureau of Labor Statistics provide some clues to what the

KIVA SYSTEMS

Robots made by Kiva Systems move product shelves on a warehouse floor. Amazon bought the company earlier this year in a step toward automating its distribution system and reducing labor costs.

next economy will look like. Seven of the 10 fastest-growing new job categories between 2009 and 2011 have the word "computer" or "software" in them, according to an analysis by Matt Beane, a doctoral student at MIT's Sloan School of Management.

Some say what's taking shape is a more productive symbiosis between man and machine—and successful businesses will be the ones that optimize it. Rodney Brooks, founder of ReThink Robotics in Boston, believes that a new type of general-purpose robot could reinvigorate manufacturing. The machines he's building aren't hardwired for any one job; they're flexible, so many types of businesses could use them for a variety of production tasks. The company aims to democratize automation the way the PC did for computing, spurring similar efficiency gains.

There's definitely good news here: more people than ever have access to affordable, powerful tools that can help them and their businesses become more productive. Take Todd Ruback, a privacy lawyer in Warren, New Jersey, who handles legal paperwork for companies that have lost sensitive data like credit card numbers. The job involves filing forms and notifying consumers in dozens of states, each with slightly different laws and deadlines. He's been testing software made by a company called Co3 Systems that automates much of the process. It walks attorneys through what they need to do and prints out the right form letters for each state.

Ruback estimates that the software cuts the time it takes him to handle a case by 10 to 20 percent. But lawyers bill by the hour, so why would Ruback want something that makes it all go faster? It's pretty simple, he says. The software makes him more efficient. And if he doesn't automate, the other guy will. ■

Antonio Regalado is *Technology Review*'s senior editor for business.

A 2010 photo shows assembly line workers at a Foxconn plant in Shenzhen, China.

ASSOCIATED PRESS

EMERGED TECHNOLOGIES

Migrant Workers in China Face Competition from Robots

China's giant electronics supplier Foxconn eyes automation on the assembly lines.

By CHRISTINA LARSON

One of the defining narratives of modern China has been the migration of young workers—often girls in their late teenage years—from the countryside into sprawling cities for jobs in factories. Many found work at Foxconn, which employs nearly one million low-wage workers to hand-assemble electronic gadgets for Apple, Nintendo, Intel, Dell, Nokia, Microsoft, Samsung, and Sony.

So it was a surprise when Terry Guo, the billionaire CEO of Foxconn, said last year that the manufacturing giant would add up to one million industrial robots to its assembly lines inside of three years.

The aim: to automate assembly of electronic devices just as companies in Japan, South Korea, and the United States previously automated much of the production of automobiles.

As one of China's largest private employers, Foxconn has played an outsize role in China's labor story. It has used cheap labor to attract multinational clients but now faces international scrutiny of its pay and working conditions. "Automation is the beginning of the end of the factory girl, and that's a good thing," says David Wolf, a Beijing-based strategic communications and IT analyst. Wolf, who has visited many Chinese factory floors, predicts an eventual labor shift similar to "the decline of seamstresses or the secretarial pool in America."

Since the announcement, Guo hasn't offered more details, keeping observers

guessing about whether Foxconn's plans are real. Trade groups also haven't seen the huge orders for industrial robots that Foxconn would need, although the company may be developing its own robots in house.

"Guo has good reasons for not waving his flag about this too much," says Wolf. Keeping quiet could give Foxconn a jump on competitors. What's more, with the Chinese economy slowing down, "it is politically inadvisable to talk too much about replacing people with robots," he says.

China's leaders see employment as essential to maintaining a harmonious society. The imperative of creating jobs often trumps that of efficiency. For instance, Wang Mengshu, deputy chief engineer at China Railway Tunnel Group, says that labor-saving equipment isn't always used even when it's available. "If all the new tunnels were built with the advanced equipment, that would trim the need for the employment of about six million migrant workers," he says. "In certain fields we don't want to have fast development in China, in order to solve the national employment problem."

About 300,000 Chinese workers currently live in dormitories at Foxconn's Longhua factory complex, where Apple products are assembled. Most spend their days seated beside a conveyer belt, wearing white gowns, face masks, and hairnets so that stray hairs and specks of dust won't interfere as they perform simple but precise tasks, again and again. Each worker focuses on a single action, like putting stickers on the front of an iPhone or packing a finished product into a box. As managers told ABC's *Nightline,* which aired a rare look inside the factory in February, it takes five days and 325 steps to assemble an iPad.

Such highly structured and predictable tasks are well suited to automation, says Jamie Wang, a Taipei-based analyst for the research firm Gartner. Industrial robots, typically equipped with a movable arm, use lasers or pressure sensors to determine when to start and finish a job. A robot can be operated 160 hours a week. Even assuming competition from nimble-fingered humans putting in 12-hour shifts, a single robot might replace two workers, and possibly as many as four.

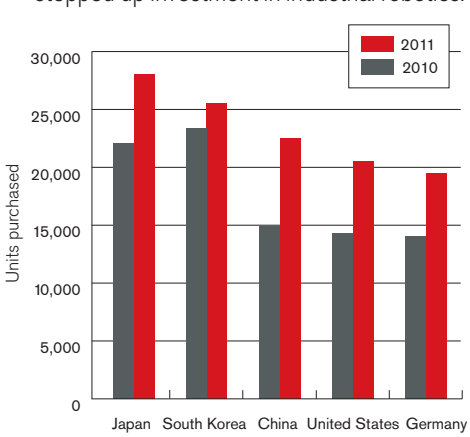
Wang stresses that Foxconn can't replace human workers right away because automating assembly lines would require rejiggering its entire manufacturing process. Larger changes in China also won't occur overnight. Smaller Chinese factories can't afford to invest in robotics, and factory wages are still relatively low—about $315 to $400 per month in the Pearl River Delta, according to Liu Kaiming, director of the Institute of Contemporary Observation, a Shenzhen-based labor organization.

Despite that, Foxconn isn't the only Chinese manufacturer betting on robots. The International Federation of Robotics, based in Frankfurt, tracked a 50 percent jump in purchases of advanced industrial robots by Chinese manufacturers in 2011, to 22,600 units, and now predicts that China will surpass Japan as the world's largest market in two years. It's obvious, Wolf says, that industrial robotics "is about to get very hot in China." ■

Christina Larson, a freelance writer in Beijing, is a contributing editor for the magazine *Foreign Policy.*

ROBOT RACE

China is among the countries that have stepped up investment in industrial robotics.



Source: International Federation of Robotics

LEADERS

When Machines Do Your Job

Researcher Andrew McAfee says advances in computing and artificial intelligence could create a more unequal society.

By ANTONIO REGALADO

Are workers losing their jobs to machines?

That was the question posed by *Race Against the Machine*, an influential e-book published last October by MIT business school researchers Erik Brynjolfsson and Andrew McAfee. They looked at falling U.S. employment and concluded that computer technology was partly to blame. Greater productivity is good, but the authors pointed out that wealth is becoming more concentrated, and more middle-class workers are getting left behind.

Technology Review spoke to McAfee at MIT's Center for Digital Business, where as principal research scientist he studies employment trends and new definitions of the workplace.

***TR*: How do you define automation?**

McAfee: The obvious definition is one fewer job than there used to be, with the same amount of output. A tax preparer can get automated away by software like TurboTax and just not find work anymore. An assembly line worker could be flat-out automated away by a robot on the assembly line. There is a closely related phenomenon, which is the massive increases in productivity brought on by digital technology. An example is the legal discovery process. By one estimate we

heard, one lawyer is now as productive as 500 used to be. You might not lay off 500 lawyers, but the next time you might hire a few people and some software to read documents.

Where is automation erasing jobs?
Others have done work showing that if you are a "routine cognitive worker" following instructions or doing a structured mental task, you have been under a lot of downward wage pressure for a while now. I think that is largely a technology story. Payroll clerks, travel agents—we don't have as many of them as we used to. We don't have as many people working in manufacturing, even though manufacturing is a growing industry.

What was the response you received to *Race Against the Machine*?
People accepted that technology was really accelerating and that there were going to be labor-force consequences. The broader discussion was between optimism and pessimism. Does it feel like we are heading into the kind of economy and society that we want, or the kind of economy and society that we don't? A lot of people who commented said, "Look, if these guys are anywhere near right, we are heading into an economy that is going to be dire for a lot of people."

What does the economy that we don't want look like?
The spread between the haves and the have-nots continues to grow, and more importantly, the absolute standard of living of the people at the middle and the bottom goes down. That is the economy that I don't want to head into.

What is the optimistic view?
Erik Brynjolfsson came up with a great phrase: "digital Athens." The Athenian citizens had lives of leisure; they got to participate in democracy and create art. That was largely because they had slaves

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"Make sure your kid's education is geared toward things that machines appear not to be very good at."

to do the work. Okay, I don't want human slaves, but in a very, very automated and digitally productive economy you don't need to work as much, as hard, with as many people, to get the fruits of the economy. So the optimistic version is that we finally have more hours in our week freed up from toil and drudgery.

Do you see evidence for a digital Athens on the street, in the real economy?
No. What we are seeing—and this was pretty much unanticipated—is that the people at the top of the skill, wage, and income distribution are working more hours. We have this preference for doing more work. The people who have a lot of leisure—I think in too many cases it's involuntary. It's unemployment or underemployment. That is not my version of digital Athens.

Which is more advanced, the automation of intellectual work or of physical tasks?
The automation of knowledge work is way, way farther along. It's really hard to get computers to do things that your four-year-old can do, like walk across the room and pick up a pen, and recognize it as a pen. So the physical world presents a lot of challenges to digital technologies.

But it feels to me as if we are starting to turn a corner. The data available to help a robot is big data, and it's exploding. The sensors have been progressing along a Moore's Law trajectory. And the physical pieces of a robot, the actuators and so on, have gotten a lot better too. So it seems the ingredients are all in place for the robots to start getting into the economy.

How should businesses react to the trend toward more automation?
I think the companies that succeed going forward are the ones that figure out what mix of human and digital labor is going to be the right mix. And I think that proper mix is going to involve more, and more types of, digital labor than we are using right now.

What is your advice to the individual, or to the parent educating a child?
To the parent, make sure your kid's education is geared toward things that machines appear not to be very good at. Computers are still lousy at programming computers. Computers are still bad at figuring out what questions need to be answered. I would encourage every kid these days to buckle down and do a double major, one in the liberal arts and one in the college of sciences.

Despite the glum view of changes in the labor market, you've used the word "cornucopia" to describe the results of innovation. What do you mean by that?
We have access to amazing digital resources. And a lot of it is all-you-can-drink, no matter what your income level is. Warren Buffett doesn't have any more Google than I have, or the unemployed person has. When I see that there are five billion mobile-phone subscriptions in the world—well, hey, that is cornucopia. It is important not to lose sight of that. ■

CASE STUDIES

An Algorithm to Pick Startup Winners

A venture capital firm throws out intuition and uses computer models to determine investments.

By JESSICA LEBER

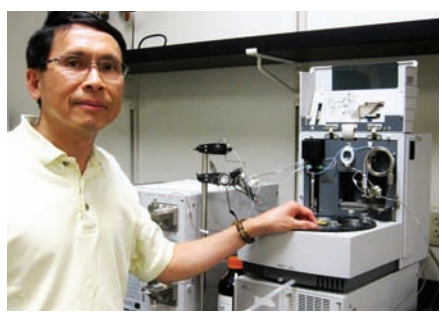
Aldea Pharmaceuticals, a startup developing an emergency treatment for alcohol poisoning, seemed like an attractive investment to venture capitalist David Coats. But he didn't rely on a hunch—he consulted the computer model he'd built.

Two weeks and a few phone calls later, he cut the company a $1.25 million check. "A decision like that would have normally taken a minimum of three months," says Tim Shannon, who is Aldea's CEO and a partner with the firm that had led Aldea's $7 million fund-raising round.

The $1.25 million was a follow-on investment from Correlation Ventures, which calls itself a "new breed of venture capital firm"—one driven by predictive analytics software built over the last six years by founder Coats and his partner Trevor Kienzle.

Correlation Ventures asks startups to submit five basic planning, financial, and legal documents. It enters these into a program similar to credit rating software.

Entrepreneurs with low scores can get their rejections in as little time as two days. High scores lead Correlation to a 30-minute interview with both the startup CEO and the outside venture firm leading the investment, plus a quick legal review and background check.



Wenjin Yang is research vice president at Aldea Pharmaceuticals, which got funding thanks to software suggesting that its method for speeding up alcohol metabolism was a good investment.

Once it makes an investment, Correlation backs off and doesn't take a board seat. That policy is itself data driven: the firm's analytics show that companies with more than two VCs on the board are less likely to be successful.

What's not yet clear is whether this system works. Correlation Ventures has so far invested in 26 companies in diverse sectors but says it is too early to grade its success.

None of this might have been possible a decade ago. Harvard Business School professor Matthew Rhodes-Kropf, who advises Correlation Ventures and is an investor in the fund, says the venture capital industry has only recently worked through enough business cycles to look for subtle trends.

There was also no complete, accurate, public set of venture capital data, so Correlation Ventures hustled for it. To build and maintain its database, it partnered with Dow Jones, scoured the Internet, signed nondisclosure agreements with more than 20 venture funds to see their internal statistics, and called hundreds of companies.

While so-called Big Data companies have attracted plenty of investors, the reputation-driven venture capital industry itself has yet to embrace their tools. (There are exceptions, such as Google Ventures, which uses quantitative analysis to help guide decisions.)

One finding from Coats's research is that while top-tier firms invest in a disproportionate share of "winning" companies, the majority of successful investments are led by venture firms that don't even crack the top 50. So it makes logical sense for Correlation Ventures to focus equal time and energy on many companies and co-invest with a diverse set of venture capital firms, he says.

To explain his project, Coats cites *Moneyball*, the book and movie about how Oakland Athletics general manager Billy Beane rejected the conventional wisdom on evaluating baseball players and built a winning franchise by letting a computer tease out variables that others overlooked. He believes the averages will work out. "We're not claiming to have a magic crystal ball," he says. "We're tilting the odds a little in our favor with each investment." ■

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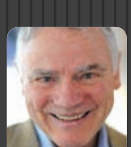

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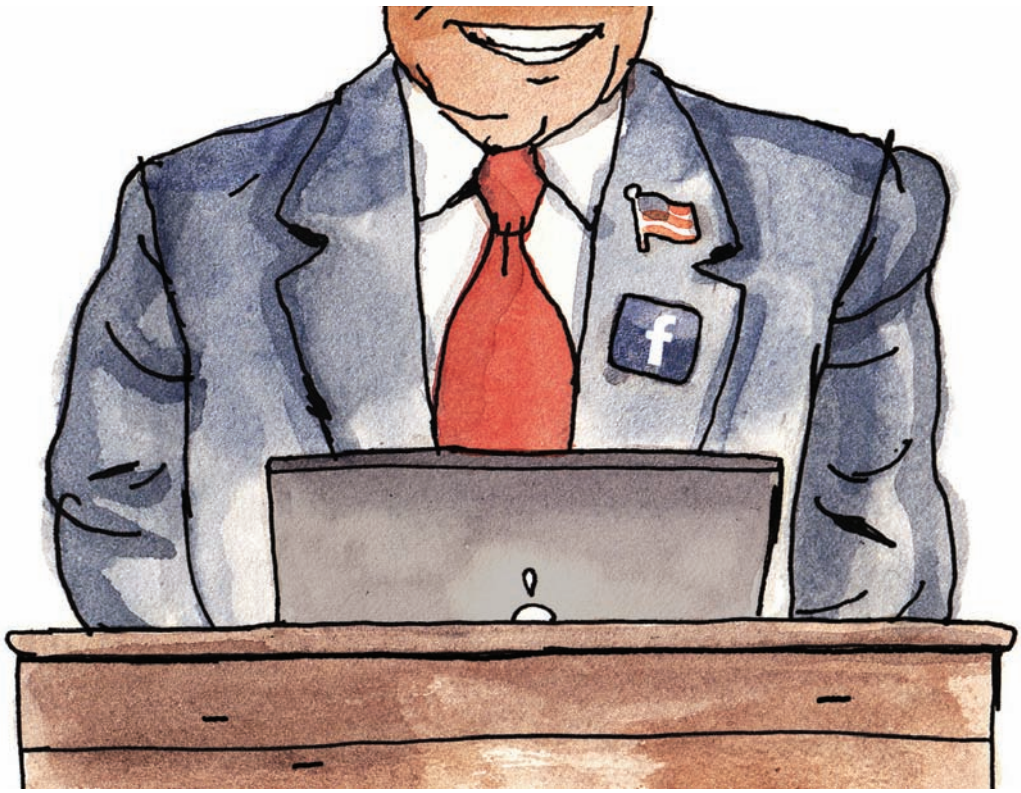


VICTOR KERLOW

Facebook: The Real Presidential Swing State

The outcome of the 2012 campaign could have less to do with grand vision than with online data analytics and peer-to-peer voter targeting.

By DAVID TALBOT

Facebook and Internet campaign strategies grew up at the same time. In 2003 and early 2004, when Facebook was a new dorm-room plaything, Howard Dean's presidential campaign pioneered Internet fund-raising. By 2008, Facebook had crossed the 100-million-user mark and was coming to dominate online social networking; that year, Barack Obama's campaign wielded a custom social-networking site that helped win the White House (see "How Obama Really Did It," September/October 2008). A Facebook cofounder, Chris Hughes, helped build that site.

Now, in 2012, Facebook is central to the upcoming presidential election. Both Obama and his Republican opponent, Mitt Romney, are well aware that half or more of the electorate is on Facebook. Both campaigns' websites are entwined with Facebook pages; visitors are encouraged to log in with their Facebook accounts and then post messages supporting the candidates for their friends to see. What Facebook also gives the candidates is an arena for testing, analyzing, and distributing precisely targeted political advertising. Both campaigns can also use Facebook to urge their supporters to vote and, potentially, to lobby their undecided friends in swing states. That means this is where the 2012 election might be won or lost—even if far more money will be spent elsewhere, especially on TV ads.

Making use of social connections can lead to the ideal form of marketing: individual messages of persuasion delivered by trusted friends. You can see the president's campaign reaching for this goal with Obama 2012, an app that his supporters can use to integrate their Facebook accounts with the campaign's website. The app's avowed task is to give people a quick and easy way to access the volunteering and organizing functions that worked so well for Obama in 2008. But the permission screen that comes with the app makes clear that it has another purpose as well. When I installed the app, I noticed that it said it would grab information about my friends: their birthdates, locations, and "likes."

Facebook's policies require that such data be used in only the context of the app itself, but even so, the campaign should be able to create tools that prompt supporters to approach voting-age friends in swing states and craft personalized appeals based on what the campaign can infer about those

President Obama's Facebook campaign app

Mitt Romney's website and Facebook page

Social Organizing tool
a Democratic Facebook app from NGP VAN

friends' interests and views. Similar tools are coming from other quarters, too. In July NGP VAN, a company in Somerville, Massachusetts, that maintains a database on all registered U.S. voters and helps Democratic candidates access the data, released a Facebook app called Social Organizing. The app lets Democratic volunteers log in with Facebook and match their friends with voters in the database. Like the Obama app, NGP VAN's makes it possible for candidates to execute a peer-to-peer persuasion strategy using Facebook.

So don't be surprised—especially if you live in a state that is considered up for grabs, such as Ohio or Florida—if you hear from an old college friend with a political pitch based on what the campaign thinks is important to you, as suggested by your Facebook data. If you've "liked" a page blaming Obama for high gas prices, you might be reminded about his pro-drilling positions.

The Obama campaign didn't respond to requests for an interview about its plans, but Joe Trippi, the Democratic strategist who pioneered Internet fund-raising for Dean in 2003 and 2004, expects that the campaign will use sophisticated methods to determine how and when to encourage peer-to-peer appeals in the final weeks of the race. "What's most important in terms of being able to reach people is to know not only that the voter is undecided—and also what issues, what is holding them up from crossing the line—but who their friends are in the network that might be able to talk to them," he says. "And then get those friends the information that says, 'We need you to talk to your friend in Pennsylvania about these three issues that matter most to them.' This is a field organizer's dream." Certainly it is more than Trippi could have dreamed of as a $15-a-day campaign worker knocking on doors in Jones County, Iowa, for Senator Edward Kennedy in 1979, carrying shoeboxes of index cards indicating whether voters said they supported Kennedy for the next year's Democratic presidential nomination.

The Romney campaign's website also encourages supporters to log in using Facebook, but it requests permission only to view the individual user's information—not information about the user's friends

> Don't be surprised if you hear from an old friend with a pitch based on what the campaign thinks is important to you. If you've "liked" a page blaming Obama for high gas prices, you might be reminded about his pro-drilling positions.

"right now," says the Romney campaign's digital director, Zac Moffatt. The same is true for the Republican National Committee's Facebook app. This may change, though, because the Republicans share Trippi's view. "I think you will start to see, on our side, that app permissions will get changed," says a Republican digital strategist who spoke on condition of anonymity. "Republicans are working on apps that take advantage of all the things in the Facebook social graph."

How much information can the campaigns glean this way? Consider that the average friend count on Facebook is 190. As of early August, more than 150,000 people were using the Obama 2012 app. Multiply those numbers and you get more than 28 million people. Now, surely many friend lists overlap, and many of those people aren't even voters. And some users block the ability of apps like Obama's to gather information about them when their friends install the programs (a *Consumer Reports* survey, however, found that only 37 percent of users touch app settings). But even if these factors make 90 percent of Obama supporters' friends useless to the campaign, the president's campaign app would still

have intelligence on 2.8 million American voters who didn't necessarily take any explicit action to share it.

Persuading just a small percentage of those people could be crucial. In 2000, the contested election that put George W. Bush in office was determined largely by 537 votes in Florida, out of six million cast in that state. And in 2004 Bush beat John Kerry by fewer than 120,000 people out of 5.6 million who voted in Ohio. (Facebook is the virtual battleground within that battleground state. In 2012, just over five million account holders of voting age lived in Ohio—out of a total voting-age population of 8.8 million, according to Well & Lighthouse, a Democratic consulting firm.) Given math like that, the right peer-to-peer and message targeting strategies "could be the difference in swing states," Trippi says.

Fast and on target

In addition to any peer-to-peer strategies they might employ, the candidates are already waging online advertising campaigns that are more scientifically designed and demographically precise than the ones Obama and John McCain deployed in 2008. Political operatives can now rapidly test ad copy across multiple demographics, getting strategic insights within hours. They can even keep track of exactly which ads individual computer owners have clicked on.

These abilities were brought to bear in an ad campaign that rolled out in March of 2010, when President Obama signed the Patient Protection and Affordable Care Act—so-called Obamacare.

The midterm elections were just eight months away, and the president was concerned for a vulnerable ally, Harry Reid of Nevada, the Senate majority leader. On the health care issue alone, Reid's online strategist, Jon-David Schlough, developed 18 sets of targeted advertisements for people in different demographic groups. For example, the version geared to students pointed out that the legislation would let them keep their parents' insurance until age 26; the one for the elderly focused on what it would do to close a Medicaid benefit gap known as the doughnut hole.

Then, for each of the 18 campaigns, different versions were tested on Facebook. Schlough says the site gave him access to a wide range of demographic groups, made it possible to place small ads at low rates, and offered easy ways to experiment rapidly with different combinations of headline, image, and text. The versions that generated the most clicks would get wider distribution on multiple websites.

Eventually, the campaign could be sure that, say, an ad about being able to stay on parental insurance plans would be shown to a specific 25-year-old four times a day for two weeks. It's called nanotargeting, and "it's now a component of all campaigns," says Schlough, the founder of Well & Lighthouse. "Political types are used to large data-set analysis on things like polling data and turnout data. But the fact that so much more data is available, so much faster, is allowing us to innovate a lot quicker."

For Reid, such innovations might have been decisive. Consider that his opponent, Tea Party favorite Sharron Angle, spent about as much as Reid and was ahead in the polls in the weeks leading up to the election. In the end, Reid won by more than 5 percentage points. tr

David Talbot is *Technology Review*'s chief correspondent.

King Natural Gas

Will cheap natural gas give us an opportunity to reduce emissions while inventing new technologies? Or will we simply become addicted to another fossil fuel?

By DAVID ROTMAN

Early this summer, a simple graph from the U.S. Energy Information Administration shocked even the most astute energy wonks. It showed that for the first time since the federal agency began keeping track, coal was no longer the dominant fuel used to generate electricity in the United States. Over the previous few months, the use of natural gas in power plants had risen so quickly that it accounted for as much electricity as coal, a far dirtier fossil fuel. (As usual, renewables such as wind and solar power flatlined near the bottom of the chart.) The milestone was just one more sign of a transformation in the energy prospects of the country—and probably the world. The sudden abundance of cheap natural gas has dramatically changed the way the United States produces and consumes energy, dwarfing the changes wrought by decades of subsidies and other incentives for the development of nonfossil fuels.

Natural gas spot prices (Henry Hub)
http://www.eia.gov/naturalgas/weekly

The so-called gas revolution is largely the result of advanced drilling techniques—horizontal drilling and hydrofracking—that have become more widespread over the last several years. These methods make it practical to extract huge amounts of natural gas that have long been known to exist in shale deposits around the country, most notably in the Marcellus shale that spreads for tens of millions of acres underneath much of Pennsylvania and parts of New

York, Ohio, West Virginia, Maryland, and Kentucky (see "Natural Gas Changes the Energy Map," November/December 2009). Experts disagree on how much recoverable gas these deposits actually hold, but by most guesses it is more than enough to supply the United States for many decades. What's more, large deposits of shale gas have been identified in China and in spots throughout the rest of the world.

Though it's been increasingly evident since the late 2000s how important this resource is, it's startling how quickly and thoroughly it has altered our energy habits. The reason has to do mainly with another statistic that the EIA carefully tracks: for much of the first half of this year, the price of natural gas hovered around $2 to $2.50 per million BTUs, far below the $13 it reached in 2008 (before the rapid expansion of drilling in the Marcellus shale). At $2.50 per million BTUs, the price of natural gas is the equivalent of around $15 per barrel for oil.

Put another way, modern natural-gas-fired power plants can now produce electricity at around four cents per kilowatt-hour. That's cheaper than energy from new coal plants, and far less than the price of even the most efficient wind or solar power when the cost of backup systems for those intermittent sources is taken into account (see chart on facing page).

"Cheap natural gas has taken a big bite out of coal very quickly," says David Victor, an energy expert at University of California, San Diego. "And there's going to be a bloodbath in wind power as well." For investors and technologists hoping to make renewable energy, such as wind and solar power, cost-competitive with fossil fuels, reaching so-called grid parity has suddenly gotten much tougher. Arguably, it's impossible to reach with existing technologies.

Indeed, economists say it is hard to overstate how significant the sudden availability of cheap natural gas is. "It is the largest change in our energy system since nuclear became part of the electricity grid 50 years ago. And I don't think we fully understand the implications," says Michael Greenstone, an economist at MIT and director of the Hamilton Project, an economic policy initiative at the Brookings Institution in Washington, D.C. The inexpensive and abundant natural gas has already been a tremendous boon for the economy, he says, creating jobs in gas-rich areas and providing cheaper electricity to consumers and manufacturers. But he cautions that it's "an open question" how it will affect climate. "There are two views," he says. "It's a 'blue bridge' to a green future, or it's the death of nuclear and renewables. I don't think we know the answer yet."

The United States is saving about 400 million metric tons of carbon emissions annually in the recent switch to natural gas from coal. That's roughly twice as much progress as the European Union has made in complying with the Kyoto Protocol through policy efforts.

Blue Elephant

Burning natural gas, which is mainly methane, produces far less carbon dioxide than burning coal. UCSD's David Victor, for one, estimates that a modern gas-fired power plant emits roughly two-fifths as much carbon as even a new coal plant. According to his calculations, the United States is saving about 400 million metric tons of carbon emissions annually in the recent switch to natural gas from coal. That's roughly twice as much progress as the European Union has made in complying with the Kyoto Protocol through policy efforts. "There is no single event that has had as large and sustained an impact on carbon emissions as the gas revolution," he says.

But optimism about the environmental benefits should be tempered. For one thing, utilities might return to using more coal as increased demand makes natural gas more expensive. Another concern is that extracting and transporting natural gas itself generates greenhouse gases. Dueling studies have published varied and sometimes contradictory estimates of the total emissions associated with natural-gas production, but the contributing factors include the energy used in the extraction process and the fact that methane—an extremely potent greenhouse gas—is released during drilling and leaks from pipelines during transport. In fact, there are no reliable measurements of how much energy drilling for shale gas consumes or how much methane actually escapes.

In any case, it's clear that switching from coal to natural gas will not come close to delivering the huge reductions in greenhouse-gas emissions that most scientists contend are needed by midcentury to ward off the worst effects of climate change. According to estimates by economist Henry Jacoby and his colleagues at

ISTOCK

MIT, the increased use of shale gas might lower carbon emissions somewhat in the next five to 10 years, but at best it will keep them flat through 2050. In other words, there is a short window of opportunity to begin inventing and deploying cleaner technologies. Jacoby predicts that natural-gas prices will stay relatively low over the next decade, climbing slowly to around $5 to $6 per million BTUs—still making it hard for renewables to compete.

The "real elephant sitting in the room," Jacoby says, is that we don't have a climate policy aimed at penalizing carbon emissions, which would provide an incentive to invest in cleaner technologies. "The benefit of renewables is simply that they don't emit carbon dioxide," he says.

Prime time

In many ways, the impact of cheap natural gas just reinforces what has become increasingly evident over a decade of investment in renewables, particularly wind and solar power: these energy sources are still far too expensive to compete with fossil fuels if their price is based solely on the cost of energy production, and they will remain so until the technologies are significantly improved. "The push to renewables has been predicated not just on climate change but on the argument that fossil fuels would get incredibly expensive," says Severin Borenstein, an economist and co-director of the Energy Institute at Berkeley's Haas School of Business. "That was never a good bet." While technologies like solar have gotten cheaper, he says, techniques for extracting and exploiting fossil fuels are also improving and present a rapidly moving target.

To many economists, the obvious textbook remedy is to establish a price on carbon emissions, through either a tax or a so-called cap-and-trade system. Various schemes for establishing such a carbon price have been proposed, but none has gained any political momentum in the United States. What's more, a growing number of economists believe that carbon pricing alone is unlikely to spur a boom in clean energy technologies.

Borenstein, for one, says that a carbon price high enough to make existing renewables cost-competitive isn't politically feasible. Rather, he suggests, we need more support for researching and testing cleaner energy sources—and a carbon price that's low enough to be politically acceptable but high enough to give investors and companies an incentive to pursue new advances. "In some ways it's a cop-out [for an economist] to say, but the reality is that scientists better come up with something," he says.

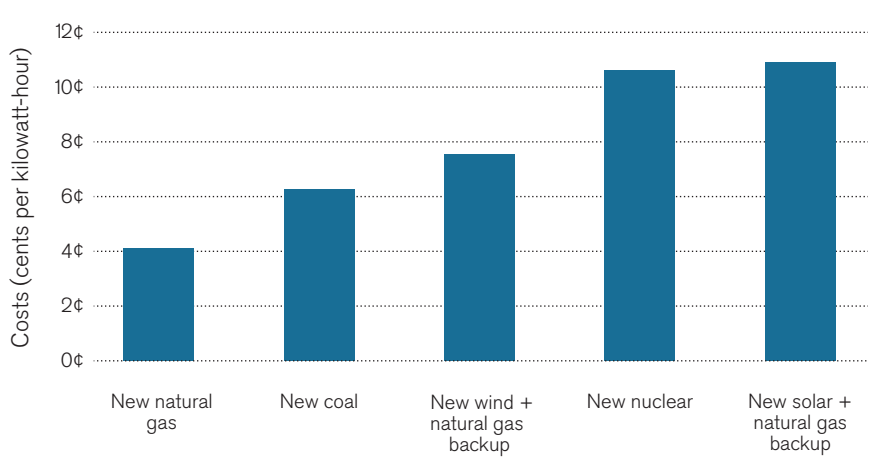
That conclusion will be a bitter one to many advocates of existing energy alternatives. But the numbers on the competitiveness of current versions of wind and solar power are clear.

"The renewables are not yet ready for prime time," says Greenstone, who has done extensive cost analysis of various electricity sources. Not only are gas-fired plants the cheapest source of electricity, but renewables are still far more expensive even if the costs to society of pollution and greenhouse-gas emissions are factored in. "If we accept that as a fact, what are we going to do for electricity for the next decade or two?" he asks. Replacing coal with natural gas can act as a "bridge" that significantly reduces carbon emissions, he adds. "Now the question is, what is at the end of the bridge? Does it really lead to the day when renewables are able to compete with fossil fuels? In the absence of pricing carbon and a substantial investment in basic research and development, that's not very likely."

Those who are developing alternatives need to accept the reality of abundant and cheap natural gas for the foreseeable future, and they must recognize the need for clean energy technologies that are far less expensive than those existing today. The good news is that many such technologies are in the works. The importance of inventing renewables that are truly competitive with fossil fuels remains unchanged. Cheap natural gas has simply emphasized, once again, how challenging finding the breakthroughs will be. tr

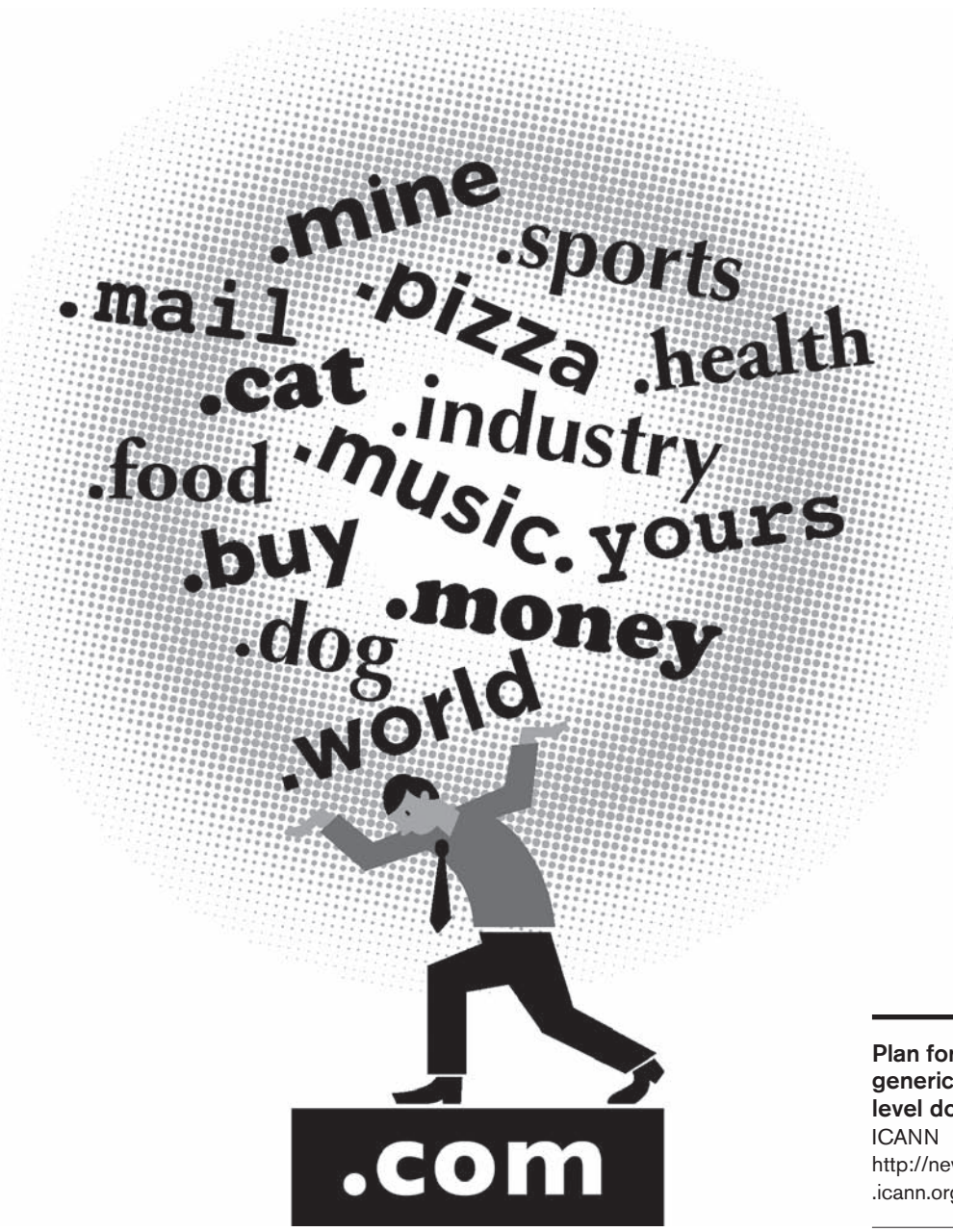
David Rotman is the editor of *Technology Review*.

Costs of electricity generation at current prices



Data reflect current prices. Costs include those of building and operating a new power plant and the cost of fuel.

Source: The Hamilton Project (June 2012)



ICANN's Boondoggle

The group that oversees Internet domain names is shaking things up for no good reason. For details, check out www.mass.confusion.

By WADE ROUSH

Modern societies depend on systems of unique identifiers. If you're a U.S. citizen, for example, it's vital that your Social Security number be yours alone, or somebody else could start picking up your checks after you retire. Similarly, it's crucial that no two phones have the same number, no two neighborhoods have the same zip code, and no two products at the supermarket have the same bar code. When an address system expands—say, when the phone companies introduce a new area code—it's almost always because the community of users has outgrown the existing scheme; it means that the old identifiers either are in short supply or aren't specific enough.

But that's not what's prompting a huge expansion of Internet domains right now. As you may have heard, the relatively manageable list of "generic top-level domains" (gTLDs) that we've all mastered over the last couple of decades, such as .com, .net, and .org, is set to expand dramatically starting next year. You could soon find Amazon at amazon.book and Google at google.search. And there may be hundreds more new top-level domains—the proposals now under review range from .aaa to .zulu. This expansion isn't happening because we're running out of unique Web addresses under the existing set of gTLDs. Far from it. It's happening because the body in charge of these things—the Internet Corporation for Assigned Names and Numbers, or ICANN—thought it would be fun and profitable.

Plan for new generic top-level domains
ICANN
http://newgtlds.icann.org

That may sound flip, but it's the simplest explanation for the coming chaos. ICANN is a nonprofit organization that was created during the Clinton administration to, among other things, loosen the control that one company, Network Solutions, exercised over the domain registration process. But now ICANN is itself a monopoly. It has the freedom to mint new gTLDs and incorpo-

STEPHEN SAVAGE

rate them into the "root zone file," the master list that matches human-readable URLs (such as www.technologyreview.com) with the numeric Internet Protocol addresses that are used to route packets between computers. And it's employing this freedom to orchestrate the biggest land rush in the history of the Internet.

During a four-and-a-half-month application period that closed on May 30, ICANN collected more than 1,900 proposals for new gTLDs. As expected, hundreds of companies applied for gTLDs corresponding to their brand names—.aetna, .barclays, .mcdonalds, and the like. But applicants also asked for the rights to hundreds of generic terms, such as .health, .mail, .music, and .pizza. The first such domains could be activated by next spring.

ICANN says it's opening up these domains to promote competition and choice in the domain-name industry. But confusion and profiteering are the more likely results. Say you come across a URL like shoes.buy. How will you know who's behind it? Amazon, Google, and three other companies have applied for control of the .buy domain; whoever gets it could sell subdomains to someone else. For example, Amazon could sell footwear at shoes.buy and charge the Gap for the rights to shirts.buy. Or say you're planning to visit Hungary. Should you go to Budapest.hu, currently the city's official site, or risk going to a new site like tourism.budapest and hope that you don't stumble onto a phishing site in the process?

> There is no general shortage of Web addresses. If there were, we might have seen businesses flocking to other new domains ICANN has already introduced over the past decade.

ICANN has built some limits into the program, including a seven-month objection period during which companies will be free to challenge aspiring trademark squatters. Even so, there's a lot of money to be made now, starting with the fees that marketers, lawyers, and consultants familiar with the domain-name business have already begun to extract from big brands. Then there are the registration fees each new gTLD owner will be able to charge for access to the new domains. Corporations cite these fees as a major worry: they're concerned that they'll be forced to defensively register their brand names and related terms across hundreds of new domains.

Through all this, ICANN could also cash in. Plenty of names are in contention—11 companies applied for .home and

another 11 for .inc, for example—and in many cases where the parties can't settle their competing claims themselves, ICANN plans to hold auctions for the domains and pocket the proceeds. That's on top of the $357 million in application fees that the Los Angeles–based organization has already collected, at a whopping $185,000 per domain. (The organization claims it needs all that money to pay for the evaluation of gTLD applications and prepare for potential litigation.)

What amazing new benefits will all this spending bring to consumers? None whatsoever, at least in the eyes of venture investor Esther Dyson, who served as chair of ICANN from its inception in 1998 until 2000. Dyson once supported the idea of allowing companies to create arbitrary top-level domains, but she says she came to believe that the change would be unnecessary and confusing for the public.

"I don't think it's illegal, but it's wasteful," she says. "One version of the future is: a lot of people spend a lot of money marketing [domain names], and a lot of new consultancies are created, and a lot of lawyers are very busy protecting and enforcing property rights, and there is no net benefit to anybody."

It's true that it's getting harder to find a great .com domain name—hence the profusion of nonsense words like Xamarin as startup names. But there is no general shortage of Web addresses. If there were a genuine clamor for additional top-level domains, one might have expected to see businesses flocking to .biz, .info, .name, and the handful of other gTLDs that ICANN has introduced over the past decade.

Opening up the Internet to a flood of new gTLDs might also have the unintended consequence of making consumers even more likely to stop thinking about URLs at all and turn instead to Google, Bing, or Baidu to locate the sites they need. It's already easy to surf the Web without ever typing a URL. As Dyson points out, "the search bar and the address bar are almost merging in browsers like Chrome." As fewer and fewer consumers resort to direct navigation, owners of new gTLDs could soon find that they have "spent large amounts of money on something that is fundamentally worthless," she says.

Bogged down

Who gave ICANN the power to make this mess? The U.S. Department of Commerce, which oversees the Internet Assigned Numbers Authority (IANA), the ultimate keeper of the root zone file. The story starts back in 1998, when Network Solutions, under contract to the U.S. military and the National Science Foundation, was still the sole registrar of new domain names. "It had become a giant business, and they were throwing their power around too much," says Dyson. Under pressure from the global Internet community, the Commerce Department announced that it would hand over responsibility for the IANA—and with it, the power to coördinate the whole system of unique identifiers on the Internet—to a new nonprofit group representing stakeholders across the industry.

What amazing benefits will all this bring to consumers? None whatsoever, says Esther Dyson, who once chaired ICANN. She says the new plan is wasteful and unnecessary.

"The moment they said that, all hell broke loose, because everybody wanted to control that body," Dyson recounts. The only person everyone trusted was Jon Postel, a researcher at the University of Southern California who had, up to then, been the IANA's primary administrator. Dyson calls him a "saint" who was widely perceived as "the heart and soul of the Internet." The coalition that formed around Postel took the name ICANN and won the contract to run the domain-name system. Dyson, who was seen as an impartial outsider, was asked to be its chair.

But the organization got off to a rocky start, she says: "We really didn't know what we had gotten into, and were not too sensitive. None of which would have mattered if Jon Postel had not had heart surgery and up and died before our first board meeting." Without Postel as its peacekeeper, ICANN had trouble raising money and was forced to survive on fees from Network Solutions and a new crop of domain-name registrars that grew up under ICANN's oversight, Dyson says.

Thus was born a financial conflict of interest that continues to this day: ICANN subsists on the very industry it purports to govern. Dyson says she "lost any faith, over time," in ICANN's ability to regulate the domain-name business.

After years of planning, ICANN's board voted in 2011 to move forward with the latest gTLD scheme. The Association of National Advertisers and other corporate lobbying groups oppose the program, which is why Dyson predicts that "the whole thing is going to be mired in litigation for a long, long time."

Meanwhile, imagine the consequences if your city council proposed auctioning off street names to companies at $185,000 apiece. It would be a creative way to fatten the city's coffers, and many companies might be interested. But others would feel forced to cough up preëmptively—IBM wouldn't want an address on Microsoft Street, after all. On top of that, every resident would have to learn the new names, and every map and street sign would have to be changed. In short, it would be a loony idea with many hidden costs. Yet it is much like the scenario ICANN has penned for the Internet. tr

Wade Roush, Xconomy's chief correspondent and editor of Xconomy San Francisco, is a former senior editor at *Technology Review*.

demo

MC10 CEO David Icke

Making Stretchable Electronics

A startup prepares to manufacture electronics that conform to skin, arteries, and organs, allowing new surgical and measuring methods.

By DAVID TALBOT | Photographs by KEN RICHARDSON

MC10, a startup in Cambridge, Massachusetts, is getting ready to commercialize high-performance electronics that can stretch. The technology could lead to such products as skin patches that monitor whether the wearer is sufficiently hydrated, or inflatable balloon catheters equipped with sensors that measure electrical misfiring caused by cardiac arrhythmias.

Microelectronics have long "depended on a rigid, brittle wafer," says David Icke, MC10's CEO. MC10 uses a few tricks to change that. To make both the hydration-sensing patch and the catheter, gold electrodes and wires just a few hundred nanometers thick are deposited on silicon wafers by conventional means, then peeled off and applied to stretchable polymers. The serpentine wires elongate when the polymers stretch, either when the balloon inflates in the heart or as the patch moves around on the skin. The electrodes measure electrical impedance to detect the electrical signals in cardiac tissue or moisture levels in the skin.

The company is building on lab prototypes made by University of Illinois mate-

01

02

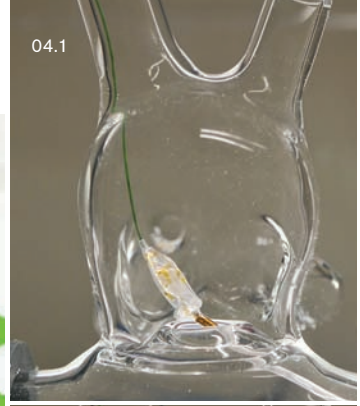
03

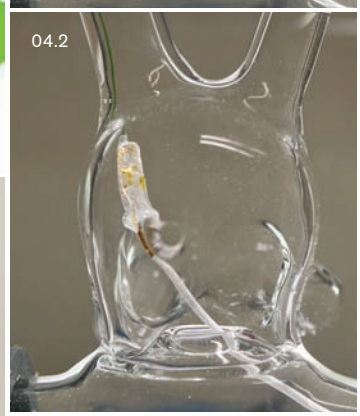
01 An MC10 engineer uses polymer tape to peel stretchable electronic components from a silicon wafer.

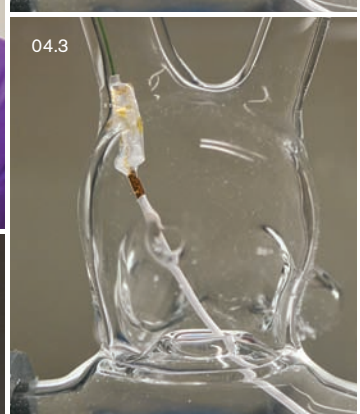
02 Layers of gold and substrates 250 nanometers thick make up 10 pairs of electrodes, which detect electrical impedance, and serpentine-shaped stretchable interconnects.

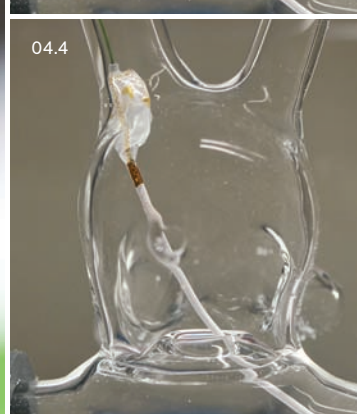
03 Mounted on a balloon catheter, these elements can sense misfiring heart tissue, allowing doctors to map and ablate damaged areas precisely.

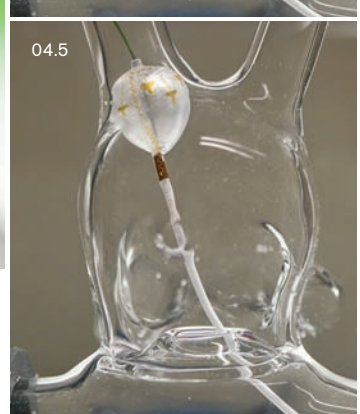
04 The finished catheter is inserted and then inflated in stages to test its performance in a glass model of a heart, which is submerged in a tank of saline water at body temperature.



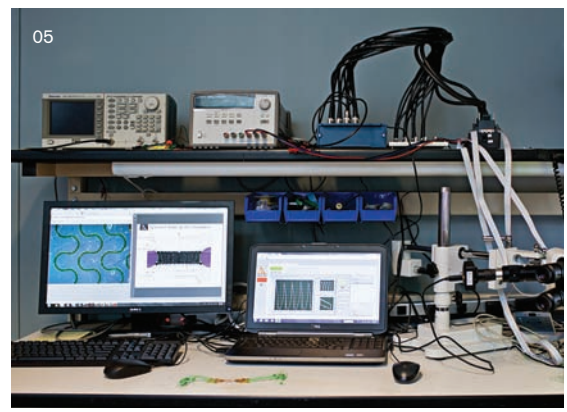


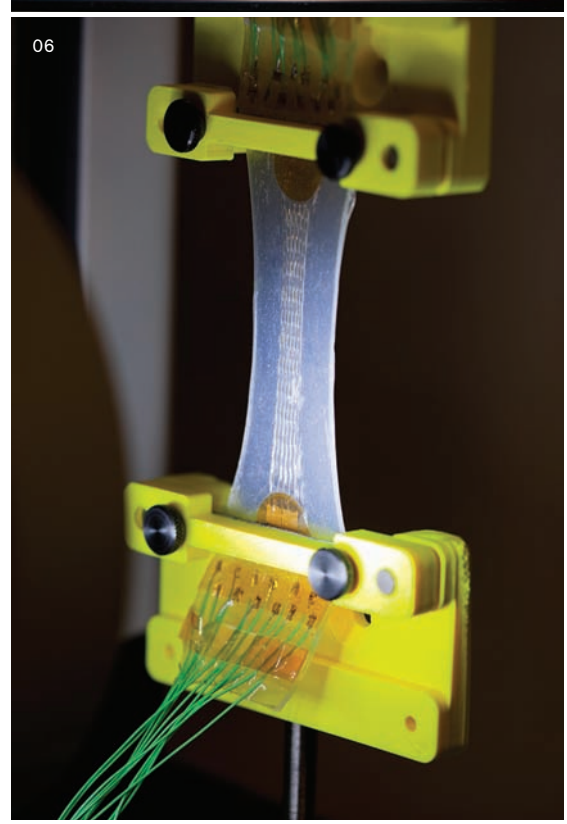






05 On an MC10 lab bench, computers monitor the performance of stretchable, serpentine-shaped gold interconnects—common to several prototype devices—as they undergo a strain test.



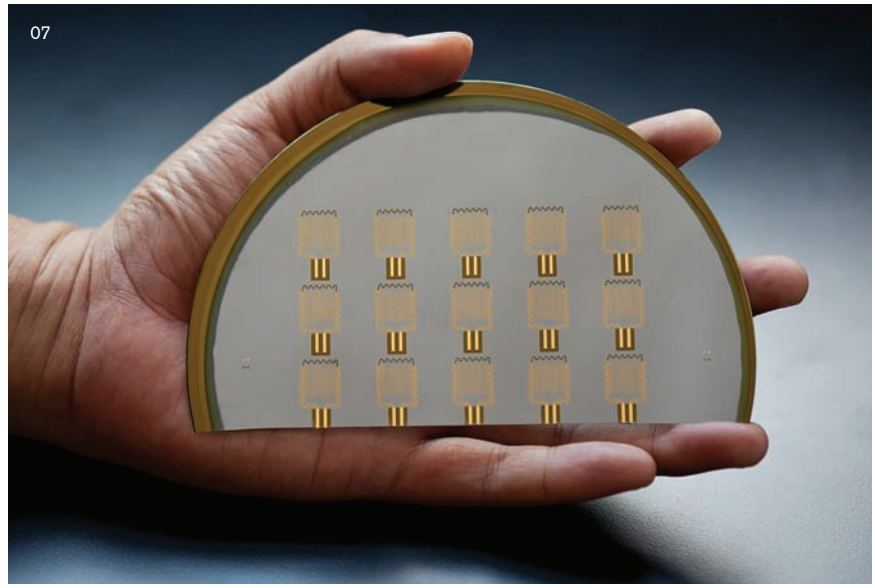


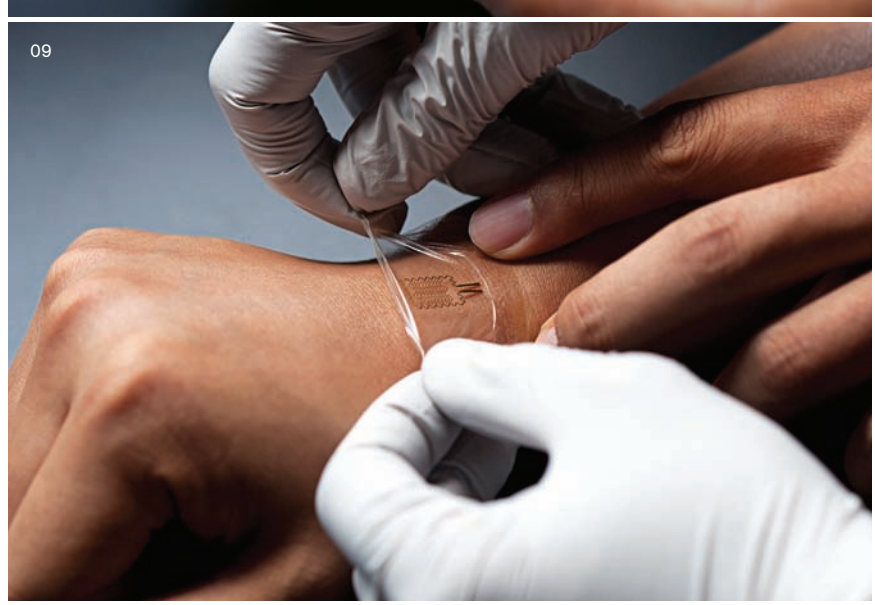
06 Gold interconnects 500 nanometers thick carry a signal even when stretched to more than 150 percent of their original length in the testing process.

07 A skin patch that detects hydration starts as one of the 15 electronic elements, each 250 nanometers thick, on this silicon wafer.

08 After being peeled from the wafer, the sensor is applied to a polymer and given a paper backing. The patch detects hydration levels by measuring the skin's electrical impedance.

09 The finished patch is applied to the skin. Its data can be read by a smartphone, or transmitted to one if a battery is added.





rials scientist John Rogers, a company cofounder. Rogers's technologies have advantages over other approaches to flexible electronics. For example, organic polymer electronics can only bend, not stretch, and they are slower than devices made of inorganic semiconductor materials or precious metals such as gold, so they can't provide precise real-time biological readings.

MC10's first product, expected to launch in late fall, will be a wearable device developed in a partnership with Reebok. The company is tight-lipped about the details. But in addition to its hydration patch, it is working on patches that use sensors to detect heartbeat, respiration, motion, temperature, blood oxygenation, and combinations of these indicators.

MC10's skin patches can wirelessly transmit information to a nearby smartphone. A phone with a near-field communication chip can be waved over the patch, or the patch can be paired with a thin-film battery made by a commercial supplier, allowing continuous data transmission.

Next up will be balloon catheters that a cardiologist could snake through the heart to detect areas of misfiring cardiac tissue. Some of the prototypes in preclinical testing have dense arrays of electrodes that allow high-resolution mapping and ablation of that tissue. Further off are other medical devices, including implantable materials that conform to brain tissue, sensing seizures and stopping them. tr

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from the labs

BIOMEDICINE

Ultrasensitive Blood Tests

Gold nanoparticles illuminate faint traces of disease

SOURCE: "PLASMONIC NANOSENSORS WITH INVERSE SENSITIVITY BY MEANS OF ENZYME-GUIDED CRYSTAL GROWTH"

Molly M. Stevens et al.

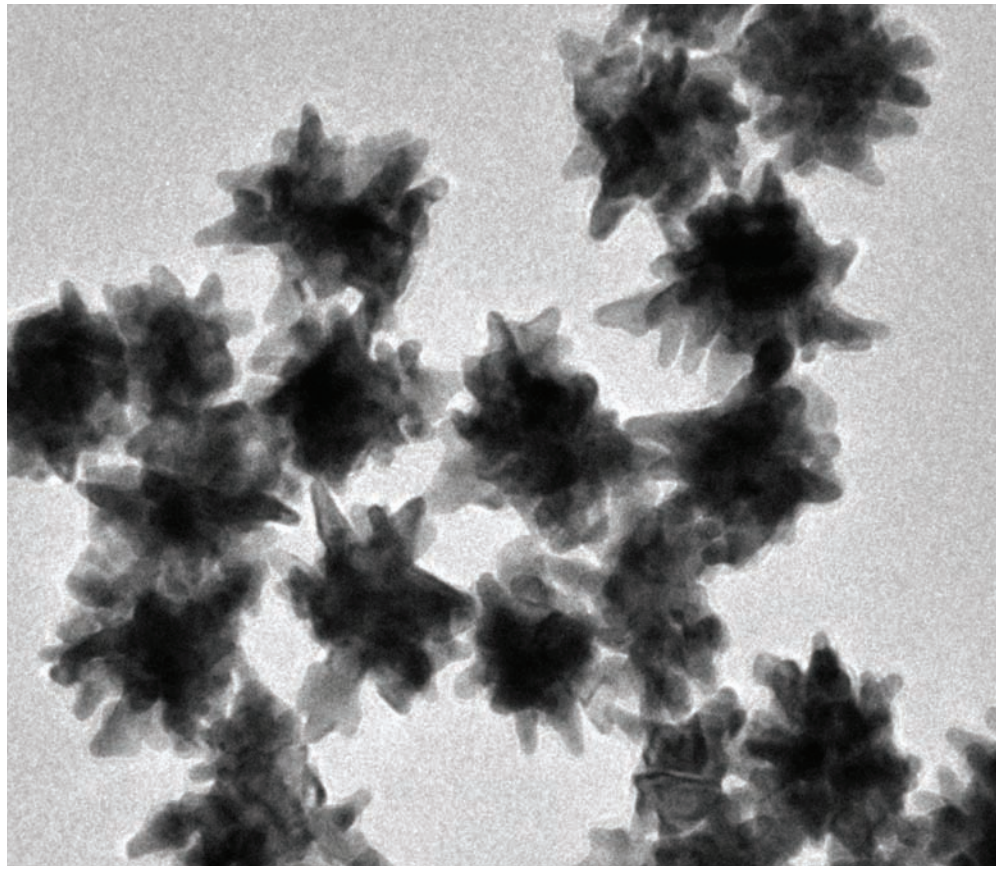
Nature Materials 11: 604–607

RESULTS: A biosensor can detect prostate-specific antigen (PSA), one of the proteins that signal occurrences of prostate cancer, at concentrations of 20 molecules per milliliter of blood. This makes the sensor at least 10 times as sensitive as existing PSA tests.

WHY IT MATTERS: Diseases can be easier to treat when discovered early, but it's difficult to measure low concentrations of proteins in body fluids. In the new test, the signal gets bigger as the concentration gets smaller, making it easier to detect very low levels of the telltale protein. The researchers believe that the technique could be adapted to help doctors detect a wide array of disease markers at early stages.

METHODS: The researchers modify gold nanoparticles and enzymes with antibodies that are known to bind to PSA. They add these assemblies, along with silver ions, to a sample of blood plasma. If PSA is present, the antibodies bind to it, which triggers chemical reactions that cause the silver ions to form silver metal. At low concentrations of PSA, the metal forms thin films on the gold nanoparticles, which causes a change in color that's easy to detect.

NEXT STEPS: The researchers are looking to commercialize their work. That will require more tests to confirm the accuracy of the approach. They are also planning to use the same mechanism to detect other conditions, such as HIV infection.



SMALL SIGNS Nanoscale gold stars, shown here through transmission electron microscopy, get tinged with silver in the presence of a protein related to prostate cancer.

Cocaine Buzz Kill

A treatment that blocks the effects of the drug could one day fight addiction

SOURCE: "AAVRH.10-MEDIATED EXPRESSION OF AN ANTI-COCAINE ANTIBODY MEDIATES PERSISTENT PASSIVE IMMUNIZATION THAT SUPPRESSES COCAINE-INDUCED BEHAVIOR"

Ronald Crystal et al.

Human Gene Therapy 23(5): 451–459

RESULTS: A vaccine-like treatment blocks the effects of cocaine by preventing it from crossing the blood-brain barrier. The treatment lasts for at least six months in mice.

WHY IT MATTERS: There is no pharmacological treatment for cocaine addiction. Because the experimental treatment works like a vaccine, it could help break the pattern of repeated relapses by blocking the pleasurable effects of the drug over long periods of time.

METHODS: Researchers had previously shown that antibodies can tightly interlock with cocaine molecules and thus prevent them from crossing into the brain. But in those experiments, the antibodies broke down within two weeks. In the new work, researchers in New York and California engineered a virus to produce the antibody continuously. A single injection of the virus was enough to block cocaine's effects in a lasting way.

NEXT STEPS: The researchers will have to continue testing the safety of the treatment in animals before beginning human trials. If successful, the method might prove effective against heroin, nicotine, and other addictive small molecules.

LAURA RODRÍGUEZ-LORENZO ET AL./NATURE MATERIALS

MATERIALS

Injectable Oxygen

Gas-filled microspheres quickly reverse oxygen deprivation

SOURCE: "OXYGEN GAS–FILLED MICROPARTICLES PROVIDE INTRAVENOUS OXYGEN DELIVERY"

John Kheir et al.

Science Translational Medicine 4(140)

RESULTS: Researchers at Boston Children's Hospital found a way to get oxygen into a body even when the lungs have stopped working: by intravenously injecting gas-filled microparticles. In anesthetized rabbits with blocked windpipes, the microspheres oxygenated the body and prevented major injury to organs for 15 minutes.

WHY IT MATTERS: Doctors and paramedics may eventually be able to use such injections to keep patients alive until longer-term methods can be employed in the hospital. Common emergency measures such as CPR and ventilators don't work if the lungs are too damaged or the airway is blocked. Heart-lung bypass machines—which oxygenate blood directly, circumventing the lungs—require some time to set up, during which the patient's organs might be damaged. Ordinarily, if oxygen gas is injected into a patient, it is likely to form bubbles in blood vessels, blocking blood flow. The microspheres prevent such blockages.

METHODS: The researchers used sound waves to mix oxygen and fatty molecules called lipids into a foam of oxygen-containing microspheres. They then selected spheres around two to four micrometers in diameter and diluted them in a solution commonly used in transfusions. The microparticles are small enough to flow through tiny blood vessels that air bubbles could block.

NEXT STEPS: More animal tests will help determine whether the microspheres could help in clinical situations such as cardiac arrest or severe bleeding. The team is also working on making the microspheres more stable, with the ultimate goal of creating an off-the-shelf treatment for emergencies.

AIR BUBBLE An intravenous infusion of oxygen-filled microparticles (the yellow sphere in this composite image) could carry the life-sustaining gas to red blood cells.

D. KUNKEL/DENNIS KUNKEL MICROSCOPY, INC.; D. BELL/HARVARD UNIVERSITY; J. KHEIR/CHILDREN'S HOSPITAL BOSTON; C. PORTER/CHRIS PORTER ILLUSTRATION

ENERGY

Heat-Driven Water Splitting

An improved catalyst could lead to cheaper ways of producing hydrogen from water

SOURCE: "LOW-TEMPERATURE, MANGANESE OXIDE-BASED, THERMOCHEMICAL WATER SPLITTING CYCLE"

Mark Davis et al.

Proceedings of the National Academy of Sciences 109(24): 9260–9264

RESULTS: A novel process for using heat to split water uses relatively low temperatures (850 °C versus well over 1,000 °C for earlier approaches) and doesn't produce toxic or corrosive intermediate products.

WHY IT MATTERS: If producing hydrogen through electrolysis can become greener and less expensive, it might be more cost-effective than getting hydrogen out of natural gas, which is a process that emits carbon dioxide. This will be especially important if automakers start selling large numbers of vehicles powered by hydrogen fuel cells.

METHODS: The researchers developed a process that uses sodium carbonate and manganese oxide to help facilitate water-splitting reactions. These materials are modified by a series of chemical reactions that change the way they react with water, producing hydrogen gas in one step and oxygen in another. The reactions form a closed cycle: at the end of the process the materials are returned to their original state, so they can be used many times.

NEXT STEPS: The researchers aim to lower the working temperatures still further, with the goal of making it practical to split water using waste heat from industrial processes and power plants.

PLATONIC IDEAL This composite image represents the ideal stimulus for Google's software to recognize a cat face.

INFORMATION TECHNOLOGY

Self-Taught Software

Google's image recognition software improves search

SOURCE: "BUILDING HIGH-LEVEL FEATURES USING LARGE SCALE UNSUPERVISED LEARNING"

Quoc Le et al.

International Conference on Machine Learning, Edinburgh, U.K., June 26–July 1, 2012

RESULTS: Researchers at Google developed software, modeled on the way biological neurons interact with each other, that taught itself to distinguish objects in YouTube videos. Although it was most effective at cats and human faces, the system could recognize 3,200 items in all, a 70 percent improvement over the previous best-performing software.

WHY IT MATTERS: The approach could help image recognition technology identify a much wider range of objects than it can now. That could make image search engines more powerful or help make robots better at interpreting their surroundings.

METHODS: Previous image recognition software learned to recognize specific objects by being shown examples labeled by humans, such as a series of images with faces marked. Google's system doesn't need labeled examples and can learn from any image, which means the objects it recognizes aren't limited to a small number of domains in which it has been trained. The software finds patterns in images and sorts them into categories of objects, in part by brute force: 1,000 computers worked together to sort through 10 million images from YouTube, harnessing much more processing power than is typical for image recognition systems.

NEXT STEPS: Google has moved the project out of its research division and into the part of the business responsible for search. The new techniques could be used to improve speech recognition, translation, and image search technology.

Speedier Data Storage

Improved phase-change devices could replace all forms of computer memory

SOURCE: "BREAKING THE SPEED LIMITS OF PHASE-CHANGE MEMORY"

Shi Luping et al.

Science 336: 1566–1569

RESULTS: Researchers at the Data Storage Institute of the Agency of Science, Technology, and Research in Singapore and the University of Cambridge, U.K., created a version of phase-change memory that operates an order of magnitude faster than any before, flipping from a digital *0* to a *1* in just 500 picoseconds (500 trillionths of a second). It's approximately 1,000 times faster than the type of memory it's meant to replace.

WHY IT MATTERS: Phase-change memory is a leading candidate to replace the flash memory used in memory cards, mobile devices, and newer laptop computers, because it can store data more densely and at a faster rate. The new speed record suggests it could even be fast enough to take the place of the short-term memory in computers, known as DRAM.

METHODS: Phase-change memory represents digital *1*s and *0*s by using an electric current to flip a metallic alloy between crystalline and disordered forms. Crystal growth is affected by temperature, so the researchers used a weak electric field to preheat the memory cells, enabling them to become crystalline more quickly when necessary. Tests that repeated the process 10,000 times showed that the new approach did not reduce the performance of a phase-change memory cell over time. Although the preheating technique means the memory consumes more energy, the researchers say it doesn't use much more than a conventional design.

NEXT STEPS: The researchers intend to investigate whether changes to the phase-change material or to the way the cells are preheated will deliver even greater speed increases. tr

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www.clevelandclinic.org/innovations/summit

EmTech Spain
November 14-15, 2012
Malaga, Spain
www.emtechspain.com

MITX Interactive Awards
November 20, 2012
Boston, MA
www.mitxawards.org/interactive/

World Future Energy Summit
January 15-17, 2013
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www.worldfutureenergysummit.com

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BREAKTHROUGH TECHNOLOGY IN FUEL ECONOMY

Patented in US, Japan and China, the Modular Hydraulic Powertrain (MHP) for any vehicle is an unique innovation which includes supercharged Single Cylinder Omnivorous Diesel engine with continuously variable displacement (CVD), continuously variable compression ratio (CVCR) and about three times greater fuel economy.

Such an impressive number confirms the research of the University of Michigan Automotive Research Center (http://me.engin.umich.edu/autolab/Publications/P2009_10.htm). Their research showed a 77.68 mpg on the highway and 46.50 mpg in the city fuel consumption for a mid-size passenger car by use of the CVD gasoline engine.

Additional benefits of MHP diesel include achievement of 90 mpg on any existent mid sized car by cost-effective retrofitting of the engine and automatic transmission.

This innovation is available for investment and partnership.
Contact: Grigoriy Epshteyn, Independent engineer/inventor.
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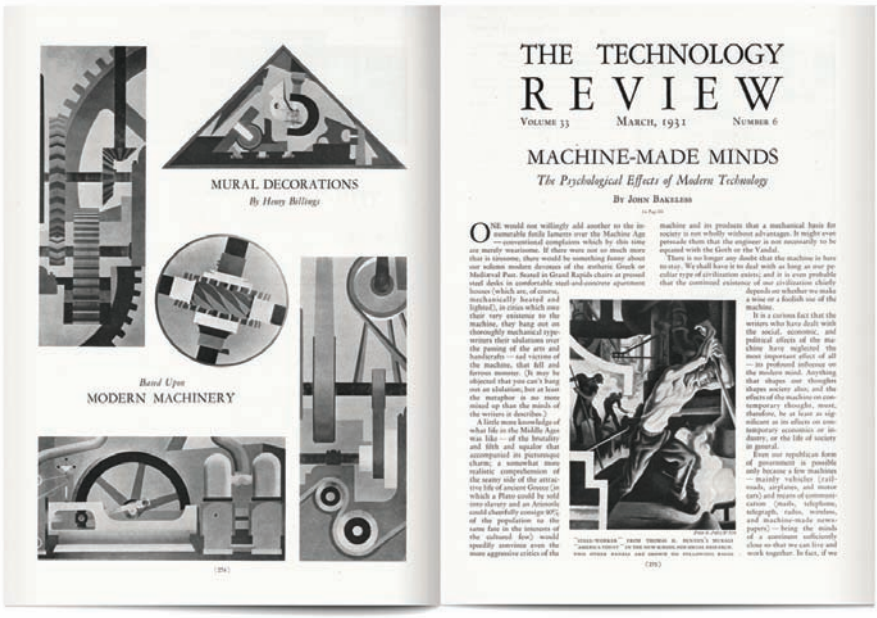

Machines Are Playing with Your Mind

The fear that our devices are somehow altering our brains might seem exclusively modern. But in 1931, *Technology Review* published "Machine-Made Minds: The Psychological Effects of Modern Technology," in which John Bakeless explored how machines had transformed the very nature of human thought. Here's what he had to say:

It is a curious fact that the writers who have dealt with the social, economic, and political effects of the machine have neglected the most important effect of all—its profound influence on the modern mind. Anything that shapes our thoughts shapes society also; and the effects of the machine on contemporary thought must, therefore, be at least as significant as its effects on contemporary economics or industry, or the life of society in general.

Even our republican form of government is possible only because a few machines—mainly vehicles (railroads, airplanes, and motor cars) and means of communication (mails, telephone, telegraph, radio, wireless, and machine-made newspapers)—bring the minds of a continent sufficiently close so that we can live and work together. In fact, if we may trust Shakespeare, who certainly was not a product of the Machine Age, "there is nothing either good or bad, but thinking makes it so." If the machine really controls our thoughts, no wonder it controls all else.

Consider the mental equipment of the average modern man. Most of the raw material of his thought enters his mind by way of a machine of some kind—often through the agency of several machines. Newspapers, magazines, moving and talking pictures are the clearest examples.

All this creates an almost incalculable difference between the modern mind—the scholar's in his study, the technologist's in his laboratory, the engineer's in the field, as well as the giggling, gum-chewing shopgirl's on her way down town in the subway—and the mind of the Eighteenth or early Nineteenth Centuries. For the first time, thanks to machinery, such a thing as a world-wide public opinion is possible.

Quite as significant as the machine-made power of the press and of mechanically reproduced art upon our minds, are the various mechanical devices developed during the last two decades for pouring ideas into our eyes and ears—movies, talkies, radio, and television. Some of these mechanical devices probably have more effect upon the less literate levels of modern society than the printed word could ever hope to have.

The danger is that our minds may be tied down to the machine. Our art may some day be restricted (as advertising art always has been) to that capable of mechanical reproduction, our music to the requirements of radio, talkie, and phonograph ... All because we have misused the machine, or allowed it to misuse us.

If the world ever realizes that hitherto Utopian vision of a general diffusion of the good things of life—an ample assurance of food, clothing, and shelter for everyone, to which is added leisure for art, letters, pure science, and philosophy, the gorgeous playthings of the mind—it will have to look for them to the machine. That is, it will have to look to the machine for the economic basis on which these things must inevitably rest.

Strangely enough, we have hitherto been willing to enslave ourselves to the machine instead of enslaving it. Most of our contemporary troubles arise from that odd willingness to allow the machine to be master instead of slave. If we are to build a great civilization in America, if we are to win leisure for cultivating the choice things of the mind and spirit, we must put the machine in its place. tr

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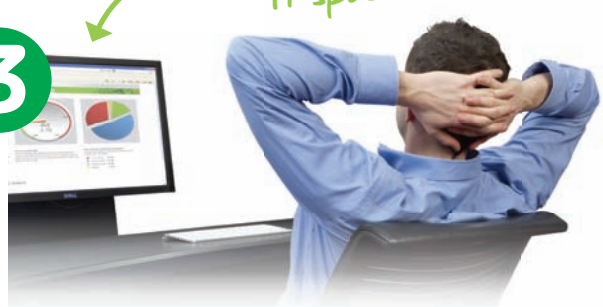

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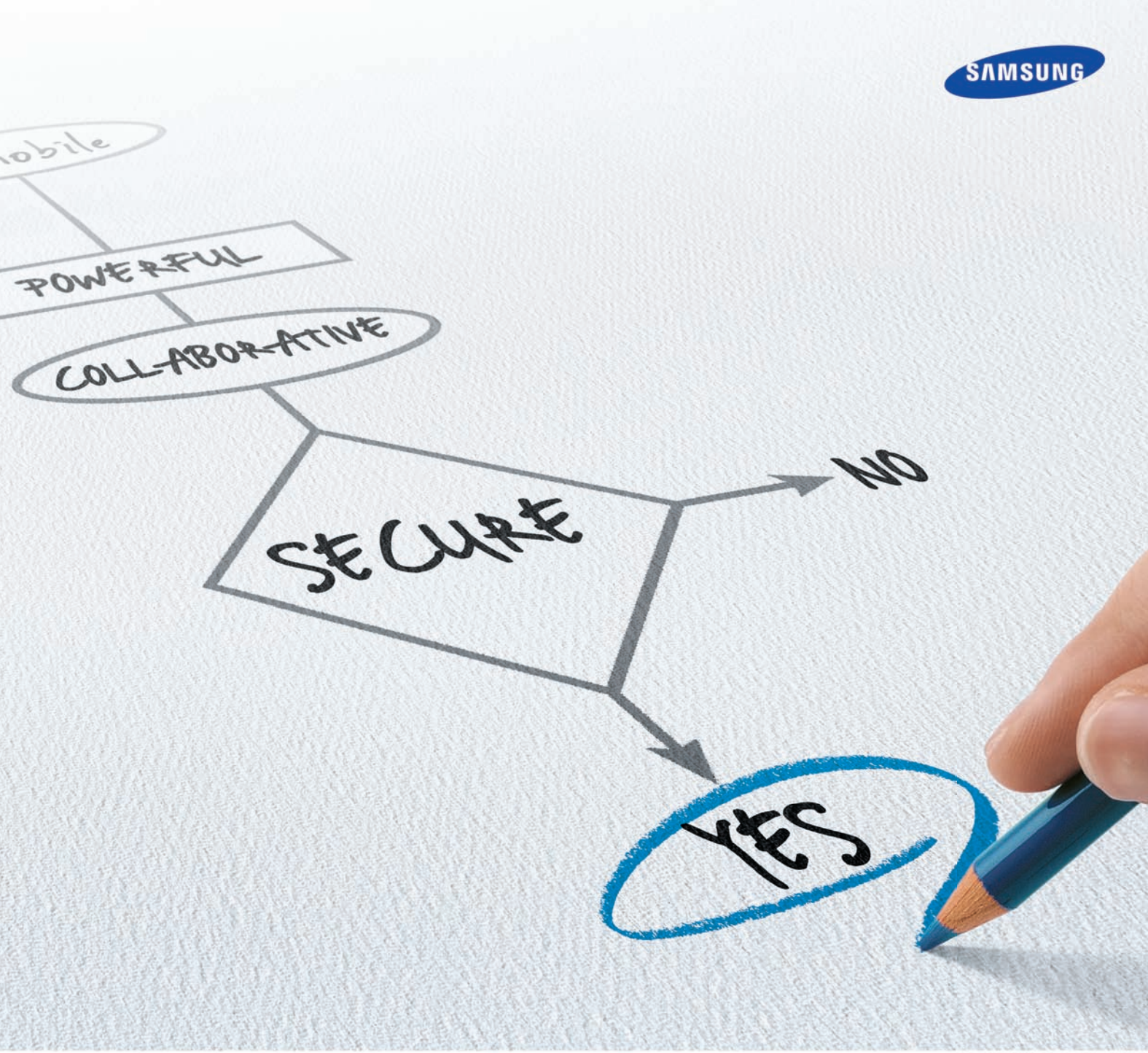

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